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The Use of Lidar for Emissions Source Opacity Determinations: Second Edition

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Lidar, an acronym for Light Detection and Ranging, is a laser radar which can be used to measure the opacity of particulate emissions from stationary sources. Extensive test results support the promulgation of the lidar technique as an alternate method to Reference Method 9, that uses trained visible emissions observers. Three tests demonstrate lidar precision and accuracy: one using an aerosol chamber to generate a controlled particulate plume, the second using an optical generator to simulate lidar return signals, the third using fabricated screen targets of constant fixed opacity. Correlation of lidar opacity values and visible emissions observations was measured by the Lidar - Reference Method 9 Collaborative Test. The Colorado Smoke Generator Test correleted lidar opacity with a calibrated in-stack transmissometer. Advantages of lidar over VEOs are the ability to measure opacity during darkness and independently of background contrast conditions, and also the lidar is not subject to time and endurance constraints. Requirements and procedures needed to facilitate routine use of lidar were developed. Twelve tables, 65 figures. Appendix A - Standards of Performance for New Stationary Sources. Appendix B - Omega 1 Lidar: Computer Software. References.

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THE USE OF LIDAR FOR EMISSIONS SOURCE OPACITY DETERMINATIONS

Second Edition

July 1981

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NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
Denver, Colorado

COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE

CONTENTS

I INTRODUCTION 1

II SUMMARY AND CONCLUSIONS 3

SUMMARY 3
CONCLUSIONS 4

III BACKGROUND 8

LIDAR. 8
OPACITY MEASUREMENT METHODS AND RELATIONSHIPS TO MASS EMISSIONS 11
LIDAR VS VISIBLE EMISSIONS OBSERVERS 11
PROMULGATION AUTHORITY 12

IV THE BASIC PRINCIPLE OF LIDAR 13

V DESCRIPTION OF THE EPA-NEIC OMEGA-1 LIDAR SYSTEM 23

VI PERFORMANCE EVALUATION AND THE CALIBRATION MECHANISM OF THE OMEGA-1 LIDAR . . . . ✓77
AEROSOL CHAMBER TESTS 80
INTERNAL CALIBRATION MECHANISM FOR THE OMEGA-1 LIDAR 92
CORRECTIVE ACTION PERFORMED ON THE OMEGA-1 LIDAR 99
FIELD EXPERIMENTATION 105

VII LIDAR SAFETY IN THE ENVIRONMENT 129

VIII USE OF THE OMEGA-1 LIDAR IN EPA ENFORCEMENT 136

REFERENCES 177

APPENDICES

A STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES - Final Rule
B OMEGA-1 LIDAR: COMPUTER SOFTWARE

TABLES

V-1 Model 624 Laser Characteristics 26
V-2 Omega-1 Lidar Receiver Characteristics 27
V-3 Optical Density vs Optical Transmittance 39
V-4 Logarithmic Channel Constants 59
VI-1 Data Sample - Aerosol Chamber Tests 91
VI-2 Latest Optical Generator Calibration Test Results 97
VI-3 Linear Channel Evaluation Test Results 102
VI-4 Logarithmic Channel Evaluation Test Results 105
VI-5 Screen Target and Statistical Covariance Test Results 107
VI-6 Colorado Smoke Generator Test - Lidar vs Smoke Generator Opacity Test Results 111
VI-7 Lidar - Method 9 Collaborative Test - Test Results for Black Smoke 119
VI-8 Lidar - Method 9 Collaborative Test - Test Results for White Smoke 124

CONTENTS (Cont.)

FIGURES

IV-1 Typical Lidar Field Set-up . . . 14
IV-2 Oscilloscope Presentation, Signal Amplitude vs Range, Uncorrected for $1/R^2$ . . . 15
IV-3 Pictoral Diagram of The Lidar Transmitter - Receiver Convergence . . . 16
IV-4 Lidar Opacity Measurement Mechanism . . . 20
IV-5 Oscilloscope Presentation Signal Amplitude vs Range, Corrected for $1/R^2$ . . . 21
V-1 Schematic Diagram of the Omega-1 Lidar System . . . 25
V-2 Linear Channel Video Signal for Clear Air, Uncorrected for $1/R^2$. . . . 29
V-3 Linear Channel Video Signal, 20% Opacity . . . 30
V-4 Logarithmic Channel Video Signal, 85% Opacity, Uncorrected for $1/R^2$ . . . 33
V-5 Logarithmic Channel Video Signal, 85% Opacity, Corrected for $1/R^2$ . . . 33
V-6 Plume Opacity vs Logarithmic Channel Video Signal Drop . . . 35
V-7 Logarithmic and Linear Channels: One-Bit Resultant Error as a Function of Opacity . . . 36
V-8 Linear Channel Video Signal 80% Opacity, Uncorrected for $1/R^2$ . . . 38
V-9 Linear Channel Video Signal 80% Opacity, Corrected for $1/R^2$ . . . 38
V-10 Suppressed Plume Spike, Linear Channel Video Signal, 20% Opacity . . . 40
V-11 Suppressed Plume Spike and Near-Region Signal, Linear Channel Video Signal, 20% Opacity . . 40
V-12 Sketches of Lidar A-Scope Backscatter Signals . . . 44
V-13 $1/R^2$ Correction Mechanism . . . 46
V-14 Computer Plots of Lidar A-Scope Backscatter Signals . . . 48
V-15 Examples of Pick Intervals - Reference Signals . . . 50
V-16 Examples of Pick Intervals - Plume data Signals . . . 51
V-17 Examples of Pick Intervals - Plume Data Signals . . . 52
V-18 Examples of Pick Intervals - Plume Data Signals . . . 53
V-19 Examples of Pick Intervals - Plume Data Signals . . . 54
V-20 Examples of Pick Intervals - Plume Data Signals . . . 55
V-21 Omega-1 Lidar: Digital Data Flow Diagram . . . 60
V-22 Omega-1 Lidar Opacity Data Analyst's Report Format . . . 67
V-23 Two-Dimensional Plot of Omega-1 Lidar Opacity Data . . . 69
V-24 Two-Dimensional Plot of Omega-Lidar Opacity Data - Continued . . . 70
V-25 Omega-1 Mobile Lidar System: View of Right Side . . . 72
V-26 Omega-1 Mobile Lidar System: View of Left Side . . . 73
V-27 Omega-1 Lidar: Generator Room . . . 74
V-28 Omega-1 Lidar: Rear View . . . 76
VI-1 Diagram of Experimental System . . . 81
VI-2 Aerosol Chamber Details . . . 82
VI-3 SRI International Aerosol Test Chamber Facility . . . 85
VI-4 Lidar-Derived Opacity Values Plotted Against Corresponding Transmissometer-Observed Opacity Values . . . 88
VI-5 Frequency Distribution and Best-Fit Normal Distribution for the Difference in Lidar and Transmissometer-Measured Opacities . . . 89
VI-6 Lidar Optical Pulse Generator . . . 94
VI-7 Block Diagram: Optical Test Signal Generator . . . 95
VI-8 Light Sources and Optical Components . . . 96
VI-9 Lidar Atmospheric Backscatter Signal, Uncorrected for $1/R^2$ . . . 98
VI-10 Lidar Atmospheric Backscatter Signal, Corrected for $1/R^2$ . . . 98
VI-11 Lidar Receiver Time Cycle (each shot) . . . 103
VI-12 Omega-1 Lidar: Photomultiplier Tube (PMT) Linearity . . . 106
VI-13 Test Results: Lidar-Colorado Smoke Generator Test . . . 113
VI-14 Correlation Plot of Test Results, Lidar-Colorado Smoke Generator Test . . . 114
VI-15 Individual Data Run - Colorado Smoke Generator Test . . . 115
VI-16 Test Results for Black Smoke, Lidar-Method 9 Collaborative Test . . . 120
VI-17 Plot of Lidar and VEO Opacity vs Smoke Generator Data, Lidar-Method 9 Collaborative Test . . 121
VI-18 Differences in Average Opacity Values - Test Results for Black Smoke, Lidar-Method 9 Collaborative Test . . . 122
VI-19 Test Results for White Smoke, Lidar-Method 9 Collaborative Test . . . 125
VI-20 Plot of Lidar and VEO Opacity Data vs Smoke Groundwater Data, Lidar-Method 9 Collaborative Test . . . 126
VI-21 Difference in Average Opacity Values - Test Results for White Smoke, Lidar-Method 9 Collaborative Test . . . 127

CONTENTS (Cont.)

FIGURES (Cont.)

VIII-1 Range Calculation for Plume Measurement Position 147
VIII-2 Elevation Angle Correction for Vertical Plumes 152
VIII-3 Laser Beam Inclination Angle Correction Requirement. 155
VIII-4 Correction in Opacity for Drift of the Residual Region of an Attached Steam Plume. 157
VIII-5 Pictoral Diagram of the Running-Average. 165
VIII-6 Cyclic Process 166
VIII-7 Cover of Lidar Log Book 170
VIII-8 Lidar Log Control Number Tabulation 171
VIII-9 Lidar Log of Operations - Sheet 1 172
VIII-10 Lidar Log of Operations - Sheet 2 173
VIII-11 Omega-1 Lidar Opacity Data: Final Report Format 175

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I. INTRODUCTION

This document technically supports the use of lidar to mechanically measure the opacity* of visible particulate emissions, commonly called smoke plumes, from stationary sources. Being formally promulgated by the U.S. Environmental Protection Agency (EPA) as Alternate Method 1 to Reference Method 9** under authority of the Clean Air Act, this lidar method provides an alternative to measuring plume opacity with the human eye by visible emissions observations (VEOs). Lidar, an acronym for Light detection and ranging, is a laser radar (ranging system) used in diverse scientific and remote sensing applications

Lidar, initially used for meteorological studies of the lower atmosphere in 1963, has been developed as a remote monitoring technique to measure stack emissions exit velocities, and gaseous pollutants such as sulfur dioxide, ozone, and nitrogen oxides. From 1967 through 1975, lidar technology was specifically developed to provide a remote monitoring instrument to measure smoke plume opacity.

In 1971, Reference Method 9 was the first opacity measurement method promulgated in the Federal Register (36 FR 24895). Using this procedure, trained visible emissions observers visually determine the opacity of emissions from stationary sources. This method has been used extensively throughout the country for the past 10 years.

The National Enforcement Investigations Center (NEIC) of EPA has applied lidar technology to the task of measuring plume opacity for enforcement purposes. NEIC designed and purchased a mobile (truck-mounted) lidar system for this purpose in 1977. Performance evaluation and field experimentation tests have been performed to establish the validity and applicability of using lidar to effectively measure plume opacity with consistent accuracy and nonsubjectivity.

---

* *Opacity is defined as one minus the optical transmittance of a smoke plume.*

** *Reference Method 9 is published in Appendix A of Title 40, Part 60 of the Code of Federal Regulations (40 CFR 60).*

To establish the basis of support for the promulgation of Alternate Method 1, the following objectives were derived:

- Establish the special advantages of Alternate Method 1 over Reference Method 9.
- Document the accuracy of the lidar instrument's ability to measure opacity against, or compared to, a known calibrated standard.
- Document the precision of the lidar measurement using screen targets of constant opacity.
- Document the correlation between Alternate Method 1 and Reference Method 9.
- Establish the field usage and data analysis requirements, including any limitations, to routinely use lidar in the remote measurement of plume opacity.

This document briefly discusses the history of lidar, along with the instrument's basic principle and its application to the quantitative measurement of smoke plume opacity. The EPA-NEIC Omega-1 Lidar is described in detail. The performance evaluation and the field experimentation test results of this lidar are presented. The main points and requirements of the EPA Lidar/Laser Safety Program are brought forth. Finally, the requirements and procedures for the use of a lidar instrument in the enforcement of opacity standards and regulations are delineated.

II. SUMMARY AND CONCLUSIONS

SUMMARY

With the proof-of-principle of the lidar mechanism previously established, NEIC applied this state-of-the-art technology to the task of routinely measuring the opacity of visible particulate emissions from stationary sources. During an extensive period of testing and evaluation, lidar has demonstrated several special advantages over visible emissions observers; these advantages are discussed throughout this report.

Lidar accuracy was demonstrated by three tests, one using an aerosol chamber to generate a highly controlled particulate plume, another using an optical generator to simulate lidar return signals, and the third using fabricated screen targets of constant fixed opacity. During the aerosol chamber test, a preliminary performance evaluation was done for the Omega-1 Lidar, establishing its baseline capability for measuring plume opacity. The optical generator, using six opacity values from 0 to 80%, was used to verify the performance of the Omega-1 Lidar's optical receiver and associated electronics including the two video data channels, one linear and the other logarithmic. Four screens were used to determine how accurately the lidar could measure constant opacity in the presence of atmospheric influences.

The precision of lidar opacity measurements was demonstrated by the screen target test. The lidar was fired through four square-meter wire mesh screens of calibrated opacity values 30.9, 45.5, 64.7, and 75.8%, along with clear air for 0% opacity. This test determined how precisely the lidar could measure the constant opacity value of each screen, and clear air, in the presence of atmospheric influences.

The correlation between lidar opacity values (Alternate Method 1) and visible emissions observations (VEOs; Reference Method 9) was defined by the Colorado Smoke Generator Test, and the Lidar-Reference Method 9 Collaborative Test. For the first test, the Omega-1 Lidar measured opacity from the State of Colorado smoke generator that is used to certify federal and state visible emissions observers. The second test, using the Texas Air Control Board (TACB) smoke generator in Austin, compared opacity measurements of the Omega-1 Lidar to those of six certified visible emissions observers and established the average difference (positive or negative bias) between these two opacity measurement methods.

Drawing from the principle of lidar, the operational and mechanical characteristics of a lidar instrument, and the field experience gained over the past several years, EPA has developed utilization requirements and procedures for applying lidar to the routine measurement of plume opacity.

CONCLUSIONS

EPA has found that lidar is a suitable mechanism to accurately measure plume opacity during all hours of the day and night, regardless of lighting conditions or contrast between a particular background (sky, terrain, etc.) and a smoke plume. The extensive test results obtained with lidar are sound, and they strongly support the promulgation of the lidar technique as an alternate method to Reference Method 9.

Special Advantages

The use of lidar in measuring smoke plume opacity has special advantages over visible emissions observers:

> Lidar can measure plume opacity during nighttime hours as well as daylight, which cannot be effectively accomplished with Reference Method 9. A lidar contains its own light transmitter (pulsed laser) and does not depend upon sunlight to measure plume opacity.
>
> Lidar can measure plume opacity independent of background light contrast conditions, such as between a smoke plume and clear sky, cloudy sky, terrain, etc. The color contrast between a plume and the background sky or terrain has no influence on the lidar's measuring opacity.
>
> Lidar is not time- or endurance-limited as are visible emissions observers. Being mechanical in nature, lidar can measure discrete opacity values over a continuous data run or sequence from a few seconds to as long as several hours.

Lidar Accuracy

Lidar measures opacity with consistent accuracy and nonsubjectivity against a known, calibrated source. The aerosol chamber test demonstrated that the lidar measures average plume opacity 0.3% higher than the average chamber opacity for black and red particulates. The optical generator test clearly demonstrated that the lidar is capable of measuring opacity consistently to within 0.3% of the calibrated value from 0% to at least 80% opacity. The screen target test showed that the lidar measures opacity consistantly and nonsubjectively to within 1.5% of the laboratory-determined value of each of four screens of constant, fixed opacity, and for clear air.

Based on 251 opacity values ranging from 0% to 90%, obtained during the aerosol chamber test, the average lidar opacity was 0.3% higher than the average chamber opacity. The overall standard deviation of the lidar opacity values was 3.1%, which included the atmospheric variations or optical noise influences along the lidar path.

The results obtained from the optical generator test for each video channel were the following:

- For the linear video channel, the average lidar opacity was 0.2% higher than the average of the respective calibrated opacity values (from 0 to 60%) of the optical generator. The standard deviation of the lidar data was 0.6% based on 2,880 opacity values.
- For the logarithmic video channel, the average lidar opacity ranged from 0.3% lower to 0.2% higher than the average of the respective calibrated opacity values (from 20 to 80%) of the optical generator. The maximum standard deviation was 0.5% based on 1,950 opacity values.

Having 1065 opacity values, obtained during the screen target test using four screens, along with clear air (0% opacity), the average lidar opacity ranged from 1.1% lower to 1.5% higher than the laboratory-determined values of these screens. For the clear air segment, the lidar-measured opacity was 0%. A larger average difference in opacity of this test, with respect to the optical generation test, is due to optical noise on the lidar signals caused by windblown dust passing through the lidar's line-of-sight.

Lidar Precision

Lidar measures opacity precisely, as demonstrated in the screen target test using the screens of constant, fixed opacity. The test results showed that the absolute precision for clear air (0% opacity) was 1.1%. For Screen No. 1, the lidar-measured average opacity was 46.1% with the absolute precision being 1.0%. For Screens Nos. 2, 3, and 4, the lidar-measured average opacity values were 30.7, 66.2, and 74.7%, respectively, with the absolute precision values being 1.1, 0.6, and 0.4%, respectively.

Correlation of Lidar to Reference Method 9

The correlation between lidar opacity values (Alternate Method 1) and visible emissions observations (Reference Method 9) has been measured: if Alternate Method 1 indicates noncompliance with opacity standards or regulations, so will Reference Method 9. Based on the Lidar-Reference Method 9 Collaborative Test and the definition of correlation, which states that 0% opacity by Reference Method 9 is defined as being less than or equal to 5% opacity by lidar measurement, opacity values calculated from lidar data, using Alternate Method 1, shall be lowered by 5% to insure consistency between the methods.

For the black smoke segment (20 data runs) of the Lidar-Reference Method 9 Collaborative Test, the overall average lidar opacity was 3% (nearest percent) higher than that from the transmissometer of the TACB smoke generator. The average of the VEOs was 2% (nearest percent) lower than the transmissometer value. The overall lidar average opacity was 4% (nearest percent) higher than the average of the VEOs.

For the white smoke segment (14 data runs) of the collaborative test, the overall average lidar opacity value was 4% (nearest percent) lower than that from the TACB smoke generator transmissometer. The average of the VEOs was 4% higher than the transmissometer value. The overall lidar average opacity was 8% lower than the average of the VEOs.

Data from the Colorado Smoke Generator Test showed that the average lidar opacity was always less than or equal to the average opacity from the generator's transmissometer, while the collaborative test indicated that the average lidar opacity was 3% higher than the generator's transmissometer for black smoke. The average lidar opacity values ranged from 0% (average difference) to 3% lower than the average opacity values from the transmissometer for 83% of the 23 data runs. All of the lidar average opacity values ranged from 0% to 6% lower. Twenty-one of the data runs were conducted using black smoke while the other two were with white smoke.

Lidar Utilization Requirements

As concluded from the field experience gained with the lidar instrument, along with its operational and mechanical characteristics, special requirements and procedures were needed to facilitate the routine use of lidar to measure plume opacity. Requirements and/or procedures were developed for the following:

- Lidar position relative to the stationary source
- Attached and detached steam plumes
- Operational restrictions
- Calculations for opacity, standard deviation, and average opacity
- Azimuth and elevation aiming angle compensation
- Lidar data acceptance/rejection criterion
- Computation of the effective or adjusted lidar opacity
- Lidar performance verification.

III. BACKGROUND

LIDAR

The first application of a lidar was for meteorological purposes in the lower atmosphere at the Sanford Research Institute[*] in 1963[1,2]. Also, early work in lidar involved the detection and recording of backscattered[**] echoes from turbidity in the upper atmosphere and the backscatter from atmospheric molecules and haze. In the time period from 1967 to 1969, the lidar was developed into a remote sensing instrument that was used in many diverse scientific applications. Also, research in this time period revealed important applications of the lidar in air pollution monitoring[3]. The major thrust in lidar field usage has been in atmospheric probing, meteorology, and air pollution monitoring.

The lidar, equipped with a pulsed ruby laser (wavelength of 694.3 nanometers, red light) for the optical energy transmitter, has been used extensively in the last 12 years, especially in the monitoring of smokestack particulate emissions along with the subsequent particulate plume dispersion characteristics and behavior as a function of local meteorological and atmospheric conditions[4-25]. In 1969, a cooperative research program was initiated to demonstrate the utility of the ruby lidar to quantitatively measure smoke plume (visible emissions) opacity.[***] The EPA Research Triangle Park (EPA-RTP), the General Electric Company, and the Edison Electric Institute[5,16,20,21] carried out studies which clearly demonstrated the proof-of-principle that a ruby lidar does effectively measure smoke plume opacity.

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[*] *Institute now called SRI International.*

[**] *Backscatter is defined as the scattering of laser light in a direction opposite to that of the incident laser beam due to reflection from particulates along the beam's atmospheric path which may include a smoke plume.*

[***] *Opacity is defined as one minus the smoke plume optical transmittance* ($O=1-T$).

During this effort, a mobile lidar system (EPA-RTP Lidar) was designed, fabricated, and field tested. The detailed evaluation of this lidar was conducted from 1969 to 1971 which yielded valuable results regarding the lidar instrumentation and its field usage[20]. The tests provided a more practicable design for the photomultiplier tube (PMT) detector. The after-pulsing, or the signal-induced noise (detector recovery behavior after plume encounter) characteristics of the lidar's PMT dictated a design change to eliminate the effects of the large optical backscatter signal resulting from the interaction between the laser pulse and the plume particulate matter. As a result, a temporal gating scheme was devised for the PMT and subsequently incorporated into the lidar system electronics. An inverse-range squared ($1/R^2$) correction mechanism was also incorporated into the lidar electronics to effectively correct for the $1/R^2$ received-signal amplitude decrease, providing an improved means of calculating plume opacity from the lidar receiver data[21].

The evaluation also provided information regarding the processing of the lidar data (lidar pulse backscatter return signal vs lidar range, called an A-scope format) in the calculation of plume opacity in addition to the need and approach for the performance verification of the lidar in the field.

In the EPA-RTP Lidar system, the electronic signal from the receiver was displayed on an oscilloscope (A-scope). The scope trace was photographed with a polaroid scope camera. Opacity was calculated from the physical measurements of the respective voltage levels or amplitudes taken from the photograph. This evaluation and subsequent studies in the field clearly indicated a need for a more accurate and reliable data processing mechanism. It was determined that the lidar receiver data should be converted from analog to a digital format and processed by a small computer or programmable calculator. Opacity calculations could then be carried out at a much faster rate than was available in this lidar.

This evaluation also pointed out a need for a viable means of system calibration in the field. Synthetic targets were designed and fabricated, using screen of appropriate mesh sizes, to simulate plume opacity values.

The optical transmittance and opacity of the five synthetic targets were quantitatively determined in the laboratory. The agreement between the laboratory value and the lidar-measured value of the opacity of each target was good. In 1975, EPA-RTP performed the calibration tests again using a set of newly fabricated screens[24]. The agreement between the lidar and laboratory-determined values was good.

In December 1975, SRI International, under contract to the EPA National Enforcement Investigations Center (EPA-NEIC), carried out a cooperative field evaluation[22] of their Mark IX Mobile Lidar. The Mark IX has the data processing features that the aforementioned EPA-RTP lidar evaluation revealed as being needed. This evaluation involved the actual field testing of this lidar with the use of a smoke plume generator, visible emissions from several industrial smokestacks (day and night), and lidar calibration test screens. This testing clearly demonstrated the value of a lidar for obtaining smoke plume opacity of stack emissions during day- and nighttime hours of operation. Its quick set-up time (approximately 5 to 10 minutes from the time the truck stopped) and ease of operation, in addition to being a remote sensor, demonstrated a great utility for the EPA enforcement monitoring program of particulate emissions. These field tests, as well as the field tests periodically carried out with the EPA-RTP Lidar, served as an excellent technical baseline for the optical, mechanical, and electronic design of the EPA-NEIC Omega-1 Lidar System. This lidar is discussed in Section V of this report.

It is noteworthy to mention that SRI has conducted extensive research (some EPA sponsored) into the optical backscatter properties and behavior of smokestack emissions as well as plume behavior/characteristics as related to atmospheric/meteorological conditions[6,11,15,17,18]. The resulting data and conclusions of this research effort are of high value at this time as well as in the application to future development of lidar as a quantitative air pollution monitoring instrument.

OPACITY MEASUREMENT METHODS AND RELATIONSHIPS TO MASS EMISSIONS

After the promulgation of Reference Method 9 in 1971 (36 FR 24895), numerous tests and evaluations have been conducted to define the relationship between the opacity and the mass concentration of particulate matter in various plumes. This definition was necessary since both opacity and particulate mass were established as emissions standards related to the emission and control of particulate matter[26]. The definition of the relationship between plume opacity and mass concentration, as related to various measurement methods, has been carried out for several source categories[27]. Collaborative and comparative studies have been conducted for the more common opacity measurement methods for several source categories including a smoke generator[28-33]. One of the opacity measurement methods evaluated was lidar[25,30].

LIDAR VS VISIBLE EMISSIONS OBSERVERS

During its development, Reference Method 9 was found to be influenced by color contrast between a smoke plume and the background against which the plume is viewed by visible emissions observers. It was also influenced by the total ambient light (luminescence contrast) present when plume opacity was being visually determined. A plume is most visible and presents the greatest apparent opacity when viewed against a contrasting background (white plumes viewed against a clear blue sky). Under conditions presenting a less contrasting background, the apparent opacity of a plume is less and approaches zero as the color contrast or the ambient light level decreases toward zero. An example is viewing a white-to-gray plume against a cloudy or hazy sky.

The measurement of smoke plume opacity with the lidar is independent of the color contrast conditions that may exist between a plume and the respective background (clear sky, cloudy sky, terrain, etc.) and ambient lighting conditions. Lidar does not consider plume-to-background contrast in measuring plume opacity. Lidar measures opacity equally well during either day- or nighttime lighting conditions because it contains its own light source, a pulsed laser. The lidar's optical receiver is blind to or not influenced by ambient sky light and the sunlight reflected from a smoke plume and any of the various backgrounds encountered in measuring opacity.

PROMULGATION AUTHORITY

Alternate Method 1 is being issued under the authority of Sections 111, 114, and 301 of the Clean Air Act, as amended (42 U.S.C. 7411, 7414, 7601). Section 60.11(b) of Part 60 of Chapter I, Title 40 of the Code of Federal Regulations was amended in 1977 to allow methods other than Reference Method 9 to be used as a means of measuring plume opacity. The final rule documenting this change is provided in Appendix A.

IV. THE BASIC PRINCIPLE OF LIDAR

A basic lidar (laser radar) consists of an optical transmitter, an optical receiver, and associated signal processing electronics. A laser is employed as a transmitter for pulsed optical energy. Usually a ruby (wavelength of 694.3 nanometers*, red light transmitter) laser is used to generate the optical or light pulses. These light pulses have a nominal peak power of 30 to 150 megawatts, with a pulse duration of 10 to 30 nanoseconds.** The optical pulses are transmitted toward a target, such as a smokestack plume, in a highly collimated beam [Figure IV-1]. The optical energy (laser pulse) is transmitted through the intervening atmosphere to the target of interest and is backscattered along this path toward the lidar receiver. The light backscattered by the atmospheric path of propagation and the target is collected by the lidar receiver, usually a reflective telescope, and detected by a photomultiplier tube (PMT). The PMT converts the optical signal collected by the telescope into an electronic signal which is, in turn, displayed on an oscilloscope for viewing by the lidar operator. The oscilloscope's presentation to the operator is in the form of backscatter signal amplitude as a function of range along the lidar's line-of-sight [Figure IV-2] which is called an A-scope presentation. There are important features of a typical scope presentation in this figure. The scope trace increased quite rapidly at the left, to a peak which corresponds to the spatial point of the convergence of the field-of-view of the lidar receiver and the beam size of the laser [Figure IV-3]. The trace then decreases or falls off in amplitude as 1/(lidar range)^2 [$(1/R^2)$] in accordance with the general lidar equation.[1] The spike in the trace represents the backscatter signal from a smoke plume. Its amplitude is much greater than that of the atmospheric return because the particulate density is far greater in the plume than in the surrounding air. The physical and mathematical treatment of the scattering of the laser light by the particulates (aerosols) in the ambient air and in a smoke plume is called Mie Scattering Theory[34-36] and will not be discussed here.

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* *nanometer = 10^{-9} meter = 10 Angstroms*

** *nanosecond = 10^{-9} seconds*

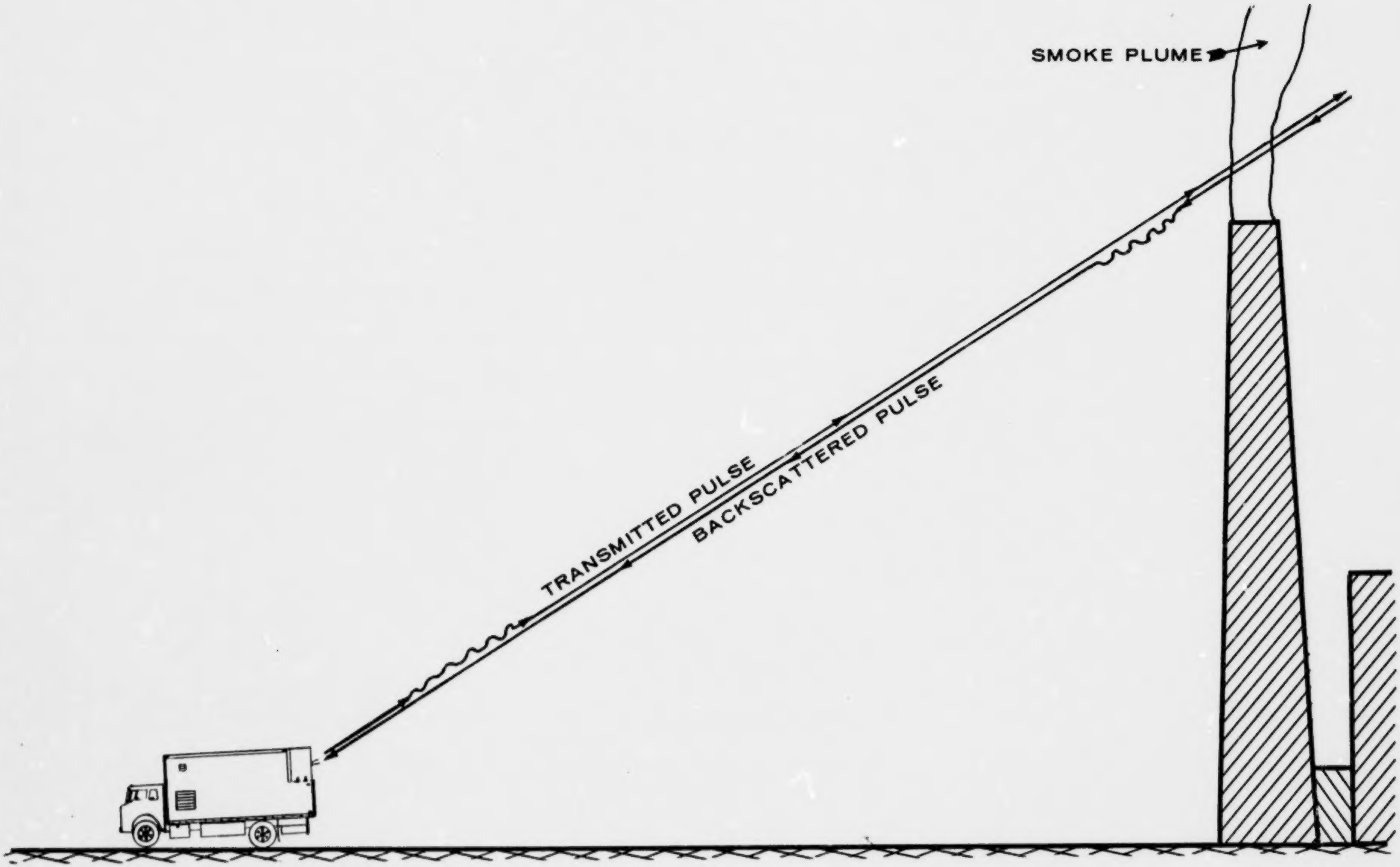
SMOKE PLUME
TRANSMITTED PULSE
BACKSCATTERED PULSE

Figure IV-1 Typical Lidar Field Set-Up

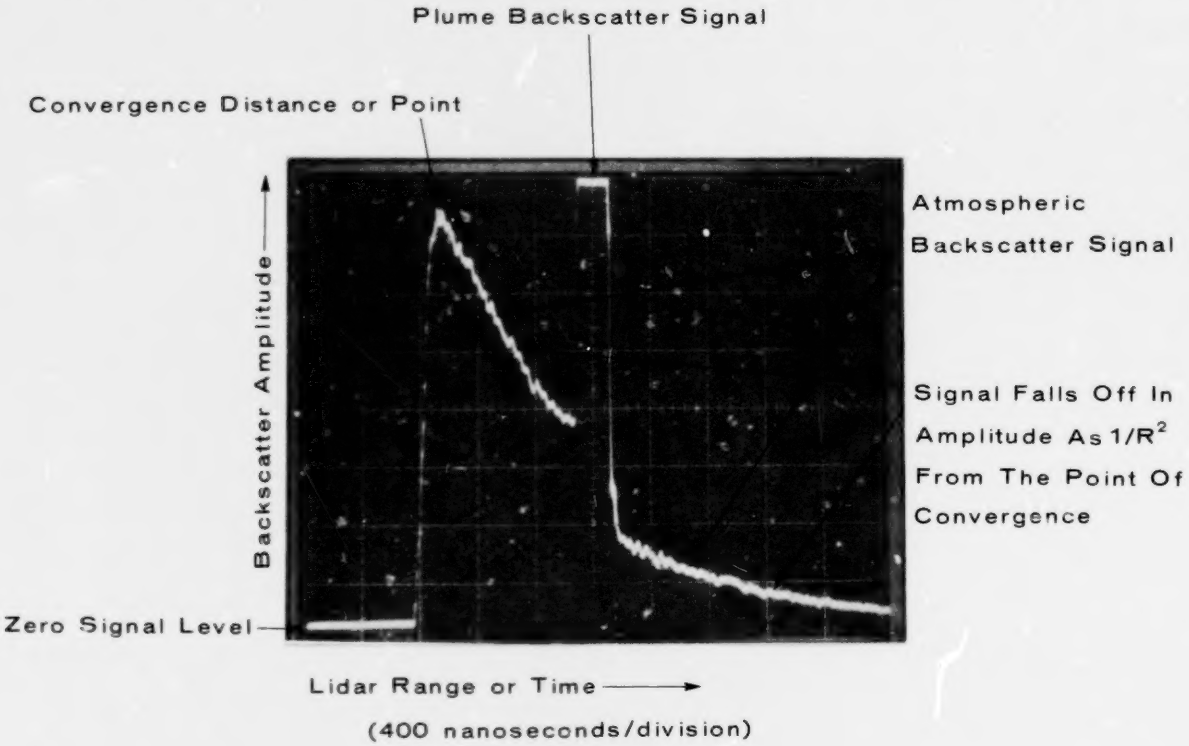

Figure IV-2 Oscilloscope Presentation, Signal Amplitude vs Range (A-Scope). Uncorrected For $1/R^2$ (Optical Generator)

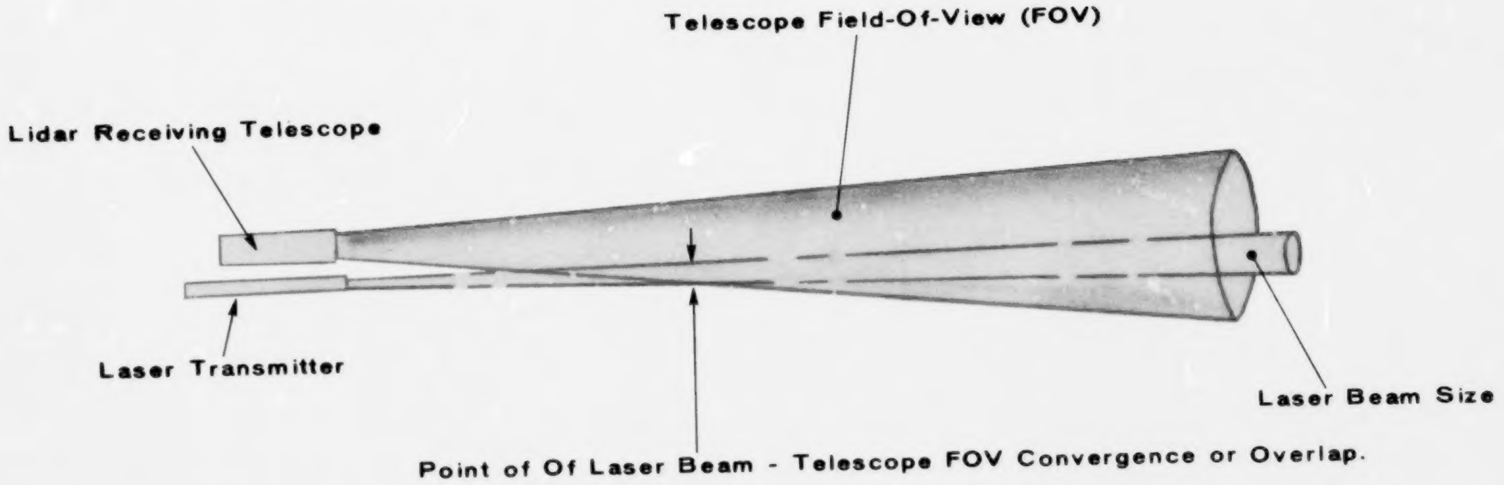
Telescope Field-Of-View (FOV)
Lidar Receiving Telescope
Laser Transmitter
Laser Beam Size
Point of Of Laser Beam - Telescope FOV Convergence or Overlap.

Figure IV-3 Pictoral Diagram of Of The Lidar Transmitter - Receiver Convergence

The behavior of the backscattered light resulting from the laser pulse propagating through the atmosphere is given by the general lidar equation[1,3,8].

$$P_r(R) = P_t \frac{L\,\beta(R)\,A_e}{R^2} \exp\left[-2\int_0^R \sigma(r)\,dr\right] \qquad \text{(IV-1)}$$

where:

$P_r(R)$	is the instantaneous received optical power at the lidar receiver, which is a function of lidar range R, $R = c(t-t_0)/2$
P_t	is the transmitted optical power at time t_o (time of transmission of the laser pulse)
L	is the effective laser pulse length, $L = c\tau/2$
c	is the speed of light,
τ	is the pulse duration $\tau = (t_1-t_0)$, which is approximately 10 to 30 nanoseconds,
t	is time,
$\beta(R)$	is the volume backscatter coefficient of the atmosphere along the path of the laser pulse,
A_e	is the effective area of the telescope receiving aperture,
$1/R^2$	is the term for the optical backscatter signal amplitude decrease as a function of lidar range. If a particle distribution backscatters laser light at a distance R from the lidar then the signal amplitude at the lidar receiver is $P_r(R)$; if an identical particle distribution backscatters laser light at a distance of $2R$, then the signal amplitude at the lidar receiver is $P_r(R)/4$.
$\sigma(r)$	is the atmospheric volume extinction coefficient along the path of the laser pulse, where r is a range variable of integration.

The exponential term given in Eq (IV-1),

$$\exp\left[-2\int_0^R \sigma(r)\,dr\right] , \qquad \text{(IV-2)}$$

is the atmospheric attenuation term where $\sigma(r)$ is integrated over the atmospheric lidar range to a target in question at range R. This equation covers a distance of 2R, a distance (lidar range) R out to the target and an equal distance back to the lidar receiver. The volume extinction coefficient $\sigma(r)$ describes the extinction of the laser pulse due to absorption and scattering by the molecules and aerosols in the atmosphere along the path of propagation. At the ruby laser wavelength (694.3nm), absorption and scattering by aerosols is the dominant effect. In relatively clear air conditions, the extinction coefficient σ is small, while in polluted air conditions, the extinction coefficient is large and the laser beam in question is attenuated quite rapidly, thus limiting the effective or probing range of the lidar.

The magnitudes of σ and β are dependent upon the wavelength of the incident lidar energy and the number, size, shape (spherical, aspherical, cylindrical, etc.) and refractive optical properties of the particles illuminated in a given unit volume. The shape, size, and number density of the particulates being emitted from an emissions source greatly influence the magnitude of the optical backscatter signal collected by the lidar receiver, as is shown by the size of the spiked plume signal with respect to the atmospheric backscatter signals in Figure IV-2.

The volume extinction coefficient of the atmosphere, σ, is generally related to the volume backscatter coefficient β which is largely due to optical scattering. A necessary condition for solving the general lidar equation is that β and σ must be related quantitatively. Knowledge of the magnitude of β and σ and their relationship is not necessary for the lidar measurement of plume opacity as is clear in the derivation of the lidar opacity equation later in this section.

Plume opacity is determined by measuring the plume transmittance (T) with the lidar. Opacity is defined as:

$$O_p = 1 - T \qquad \text{(IV-3)}$$

where:

O_p is the plume optical opacity* at 694.3 nm.

T is the plume optical transmittance at 694.3 nm.

Plume opacity is measured with the lidar in a field test set-up depicted in Figure IV-1. The fundamental measurement made with the lidar is the square of the transmittance (T^2) of the smoke plume because the lidar light pulse must pass through the plume twice. The technique of this measurement is now discussed in detail.

The lidar opacity measurement mechanism is depicted in Figure IV-4. A lidar pulse is transmitted from the laser with signal intensity I_o into the so-called lidar near-region [Figure IV-4]. Along this atmospheric path of propagation made up of molecules and aerosols which occur naturally, the lidar pulse is partially backscattered toward the lidar telescope receiver with a signal intensity I_n. The smoke plume also backscatters a portion of the lidar pulse back toward the lidar receiver with a signal intensity I_p. The remainder of the lidar pulse is attenuated as it passes through the smoke plume. The magnitude of the pulse attenuation is directly related to the transmittance of the plume. Along the far-region atmospheric path of propagation, the pulse is now backscattered toward the lidar receiver. However, this far-region backscatter signal must again traverse the smoke plume resulting in further signal attenuation directly related to the plume optical transmittance. This signal has an intensity I_f having been attenuated by the plume twice in the amount of T^2. A typical signal displayed on the lidar receiver's scope is shown in Figure IV-2. This signal is systematically corrected for the $1/R^2$ amplitude decrease or fall-off yielding a scope trace as shown in Figure IV-5.

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* *Opacity is also measured in the field through visible emissions observers trained and certified in accordance with Reference Method 9, November 12, 1974, Federal Register, 39 FR 39873.*

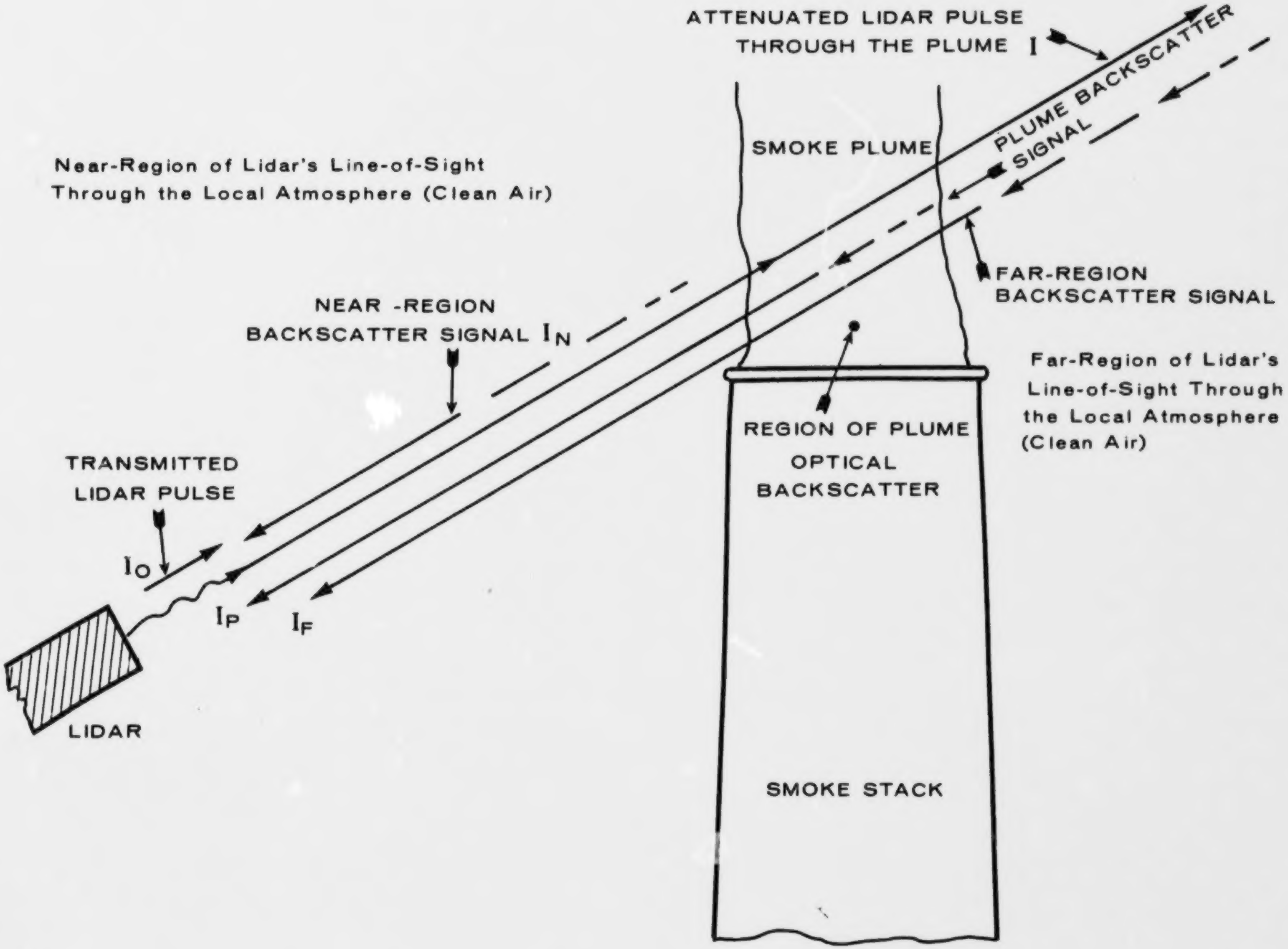

ATTENUATED LIDAR PULSE
THROUGH THE PLUME I
PLUME BACKSCATTER
SIGNAL
SMOKE PLUME
Near-Region of Lidar's Line-of-Sight
Through the Local Atmosphere (Clean Air)
FAR-REGION
BACKSCATTER SIGNAL
NEAR -REGION
BACKSCATTER SIGNAL I_N
Far-Region of Lidar's
Line-of-Sight Through
the Local Atmosphere
(Clean Air)
REGION OF PLUME
OPTICAL
BACKSCATTER
TRANSMITTED
LIDAR PULSE
I_O
I_P
I_F
LIDAR
SMOKE STACK

Figure IV-4 Lidar Opacity Measurement Mechanism

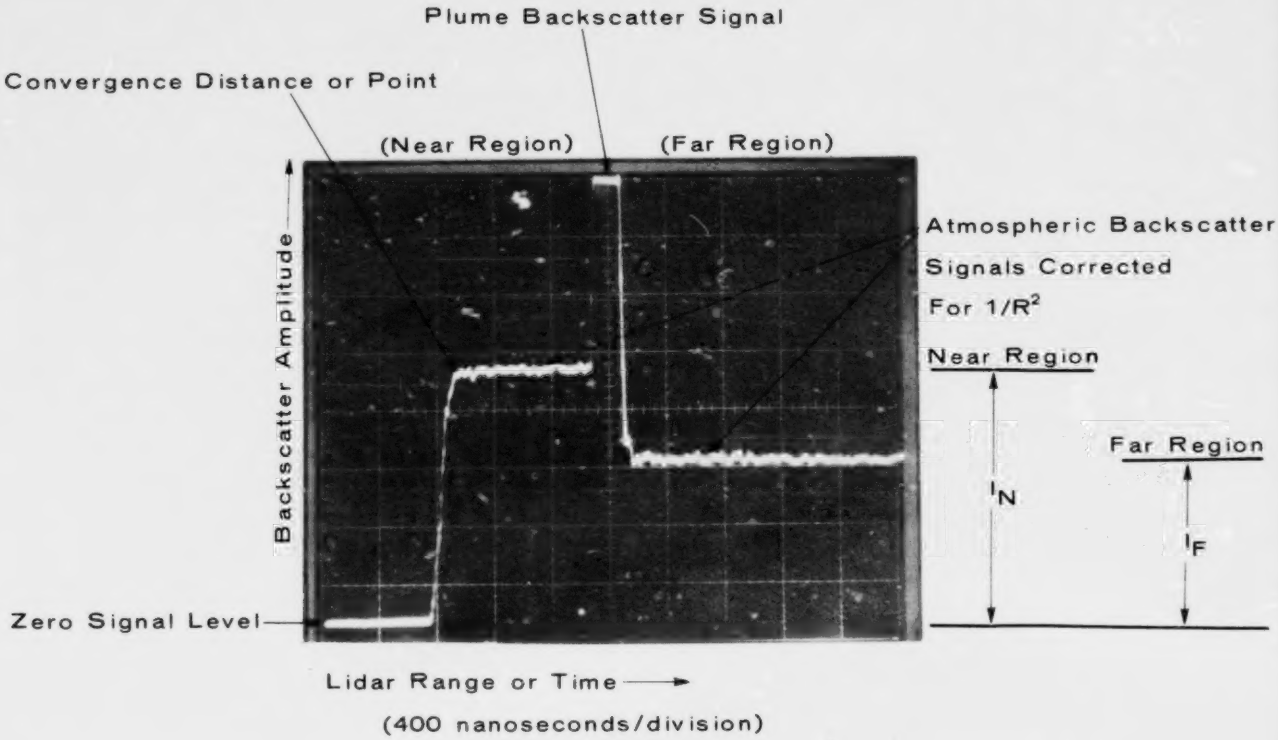


Figure IV-5 Oscilloscope Presentation Signal Amplitude vs Range, Corrected For $1/R^2$ (Optical Generator)

In a basic sense, the square of the plume transmittance is obtained by taking the ratio of I_f to I_n [Figure IV-5].

$$T^2 = \frac{I_f}{I_n} \quad \text{(Two Way)} \qquad \text{(IV-4)}$$

The one-way lidar-measured smoke plume transmittance is obtained by taking the square root of Eq (IV-4).

$$T = \left(\frac{I_f}{I_n}\right)^{\frac{1}{2}} \quad \text{(one way)} \qquad \text{(IV-5)}$$

Finally, the smoke plume opacity is given by Eq (IV-3)

$$0_p = 1 - T = 1 - \left(\frac{I_f}{I_n}\right)^{\frac{1}{2}} \qquad \text{(IV-6)}$$

To have opacity in percent, 0_p is multiplied by 100.

The backscatter signal [Figure IV-4] from the smoke plume is not used for the measurement of plume optical transmittance or opacity. This signal is used to monitor plume drift and dispersion behavior as well as the spatial and temporal combining of two or more smoke plumes located in close proximity of each other.

Research[5,11] has shown that valid optical smoke plume opacity measurements may be made by observing the near- and far-region clear air returns [Figure IV-4] at the ruby lidar wavelength of 694.3 nm. The lidar has been used in the field for measuring the opacities of actual visible emissions plumes.[22] The field tests were quite successful during both day and night plume monitoring. The ruby lidar technique is ready for use to routinely measure smoke plume opacity on a single shot basis or over-extended periods of time with a variable pulse rate up to 1 pulse-per-second.

V. DESCRIPTION OF THE EPA-NEIC OMEGA-1 LIDAR SYSTEM

The research and development that has been carried out within EPA and in private institutions has provided the necessary technical base for the design, fabrication, and testing of the Omega-1 Lidar. Research lidar instrumentation had been conceived, designed, and tested in the laboratory environment and in the field, providing much technical and operational insight into the requirements of a lidar system in addition to the pragmatic considerations that are encountered in the field. All parts of the lidar system from the laser transmitter through the data processing electronics to the computer have been optimized and improved for field use in enforcement applications. The design for the vehicle, within which the lidar is mounted, was derived from the information obtained from the research lidar units.

In late 1975 and early 1976 the Omega-1 Lidar design was formulated and a technical specification was prepared. In mid-1976 a contract for the construction and testing was awarded to the General Electric Company. This Company also fabricated the EPA-RTP research lidar several years prior, which served as a technical building block for this lidar.

It is noteworthy to mention that the lidar mechanism is applicable to measuring smoke plume opacity at numerous wavelengths of laser radiation in the visible and infrared regions of the optical spectrum. The ruby laser was chosen for the Omega-1 Lidar for the following reasons:

- The red light (λ = 694.3 nanometers) is not absorbed by atmospheric gases including water vapor.
- The optical attenuation (extinction) of the red light as it passes through particulates in a smoke plume is slightly less than for green or white light. The measured opacity of a given plume would be slightly less for red light than for green or white light.
- The ruby laser is very reliable, especially in a truck-mounted environment.

- There is a large amount of technical information regarding the optical properties of the atmosphere as measured and monitored with the ruby laser.

The Omega-1 Lidar consists of the following major assemblies:

1. Laser transmitter assembly
2. Optical receiver assembly
3. Pedestal assembly
4. Signal processing electronics
5. Automatic data processing/recording instrumentation
6. Electrical generator assembly
7. Truck/van enclosure

A schematic diagram of this lidar is given in Figure V-1.

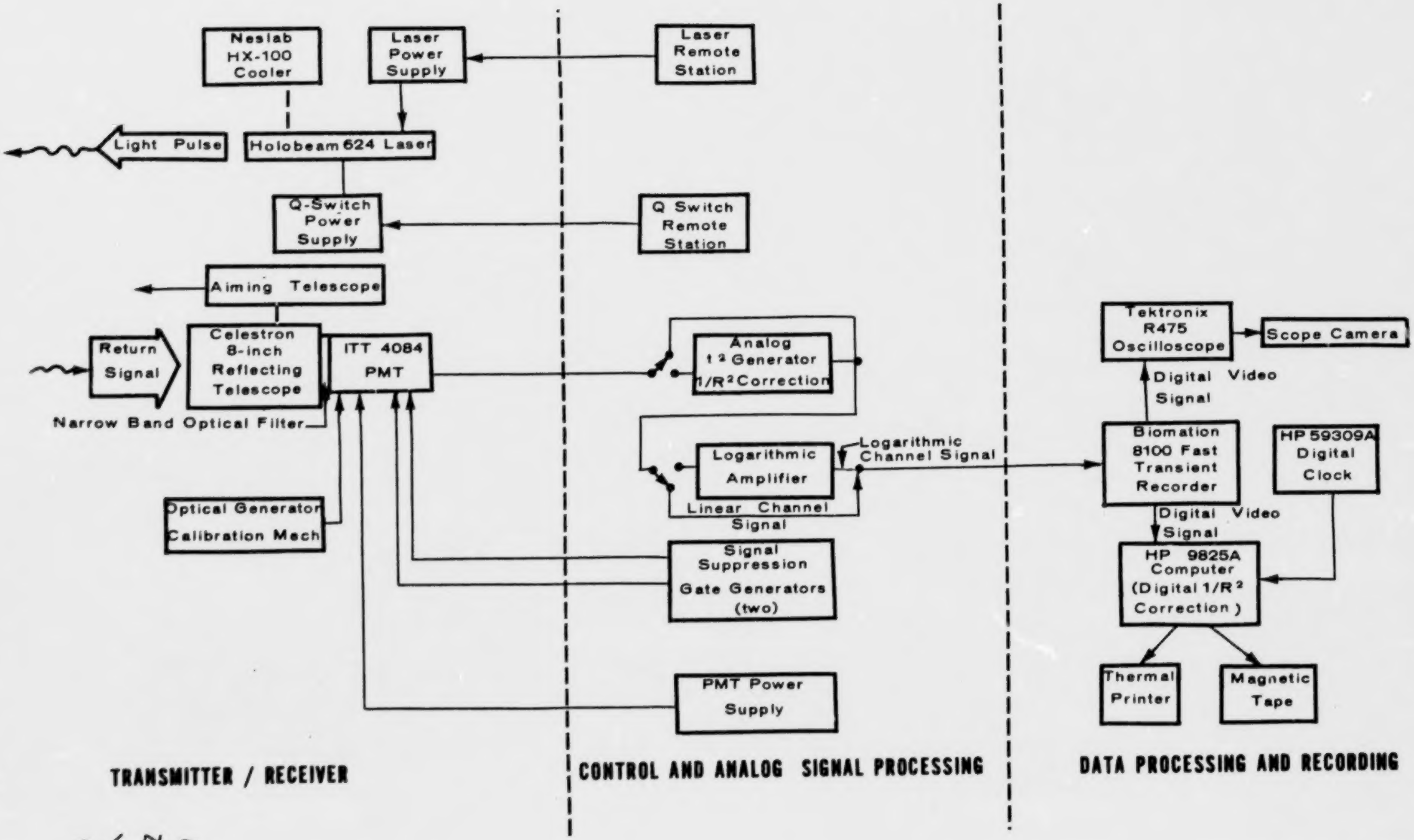

Neslab HX-100 Cooler
Laser Power Supply
Laser Remote Station
Light Pulse
Holobeam 624 Laser
Q-Switch Power Supply
Q Switch Remote Station
Aiming Telescope
Return Signal
Celestron 8-inch Reflecting Telescope
ITT 4084 PMT
Narrow Band Optical Filter
Optical Generator Calibration Mech
Analog t² Generator 1/R² Correction
Logarithmic Amplifier
Logarithmic Channel Signal
Linear Channel Signal
Signal Suppression Gate Generators (two)
PMT Power Supply
Tektronix R475 Oscilloscope
Scope Camera
Digital Video Signal
Biomation 8100 Fast Transient Recorder
HP 59309A Digital Clock
Digital Video Signal
HP 9825A Computer (Digital 1/R² Correction)
Thermal Printer
Magnetic Tape
TRANSMITTER / RECEIVER
CONTROL AND ANALOG SIGNAL PROCESSING
DATA PROCESSING AND RECORDING

Figure V-1. Schematic Diagram of the Omega-1 Lidar System

The first major assembly, the laser transmitter, is the Holobeam Laser, Inc., Model 624 Q-Switched ruby laser. Its pertinent characteristics are given in Table V-1.

Table V-1

MODEL 624 LASER CHARACTERISTICS

Wavelength of Transmitted Light	694.3 nanometers (red)
Ruby Rod Dimensions	0.95 cm X 15.2 cm (0.38 in X 6 in)
Pulse Width (FWHM)	15 nanoseconds nominally
Maximum Output	3.30 Joules (single shot) 2.95 Joules (at 1 pulse/sec)
Minimum Output	0.2 Joules (at 22°C, just above threshold)
Pulse Repetition Rate (maximum)	1 pulse/second (pps) (variable selection between single shot and 1 pps)
Laser Cooling Water	Closed Cycle Refrigerated
Laser Head Beam Divergence (full angle)	1.1 mrad, single shot 1.9 mrad, 1 pps after 25 minutes continuous operation
Laser Up-Collimator Ratio	6:1
Beam Divergence past Up-Collimator	0.2 mrad, single shot 0.3 mrad, 1 pps
Beam Diameter Out of Up-Collimator	4.0 cm (1.6 in) (effective)
Laser Optical Train Structure	Invar rails

In order to reduce the angular divergence of the laser beam, an up-collimator (collimating telescope) was incorporated on the front of the laser. It reduces the beam divergence to approximately one-sixth that of the original laser beam. The beam diameter at 1 km from the lidar is about 23 cm for single shot operation and 33 cm for the rapid fire operation (after about 25 minutes of continuous operation). At a distance of 500 meters the beam diameters are half those given above or 12 cm and 17 cm, respectively. The diameter of a plume under test with the lidar must be larger than these values for the respective lidar range values. If the plume diameter were less than the beam diameter at a given lidar range, erroneous opacity values would result, and the lidar would have to be moved closer to the source. This is not a practical constraint as most smokestacks and other sources of visible emissions produce a plume with a horizontal thickness or diameter much larger than these values.

The lidar receiver consists of a reflecting telescope for the optical collector and a light detector (photomultiplier tube (PMT)). The pertinent characteristics of the receiver are given in Table V-2.

Table V-2

OMEGA-1 LIDAR RECEIVER CHARACTERISTICS

Telescope	Celestron Pacific Model C8L f/10 Schmidt-Cassegrain Compound Telescope
Aperture	20.3 cm (8 inches)
Focal Length	203 cm (80 inches)(effective)
Field of View	4 mrad full angle
Narrow Band Pass Filter (FWHM)	13° A (FWHM) Centered at 694.3 nm at 23.9°C (75°F)
Photomultiplier Detector (PMT)	ITT Model F4084 (8 dynodes)
Lidar Aiming Mechanism	Direct view through Celestron telescope or an aiming telescope boresighted with the Celestron and the laser transmitter

The laser and the telescope are mounted side by side on a Pelco pedastal or mount that is adjusted to turn ±90° horizontally about the longitudinal axis of the lidar van, and from -10° (declination) to +90° (straight-up) in the vertical about the same axis.

The electronic video signal from the PMT detector is directed into the lidar's signal processing electronics forming two video channels:

- Linear channel
- Logarithmic channel

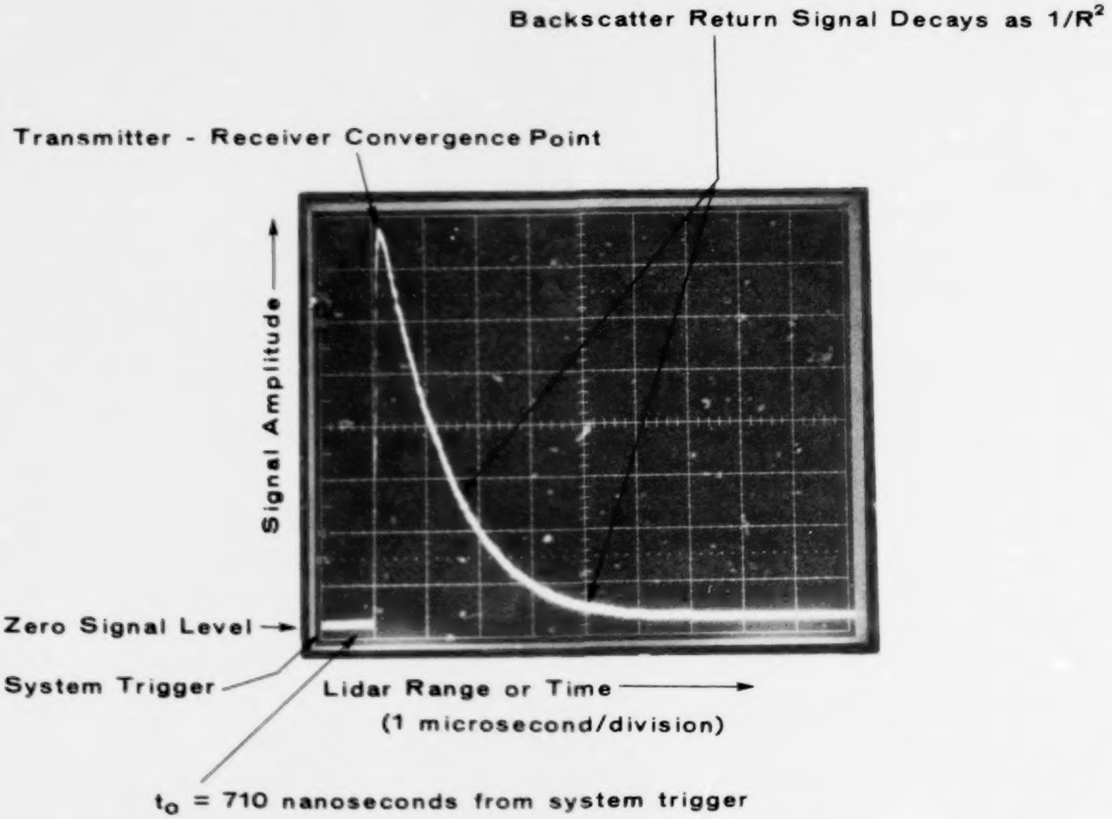
Linear Channel

The signal in the linear channel is basically the PMT video signal [Figure V-1], which is linear in the PMT's specified operating range, without any additional amplification. The linear video signal varies in amplitude in direct proportion to the magnitude of the optical input signal to the PMT.

The linear channel has many uses. It is used in the measurement of plume opacity, monitoring the combining of plumes, monitoring plume dispersion characteristics and dynamics, and other uses where large video signal dynamic range is not required.

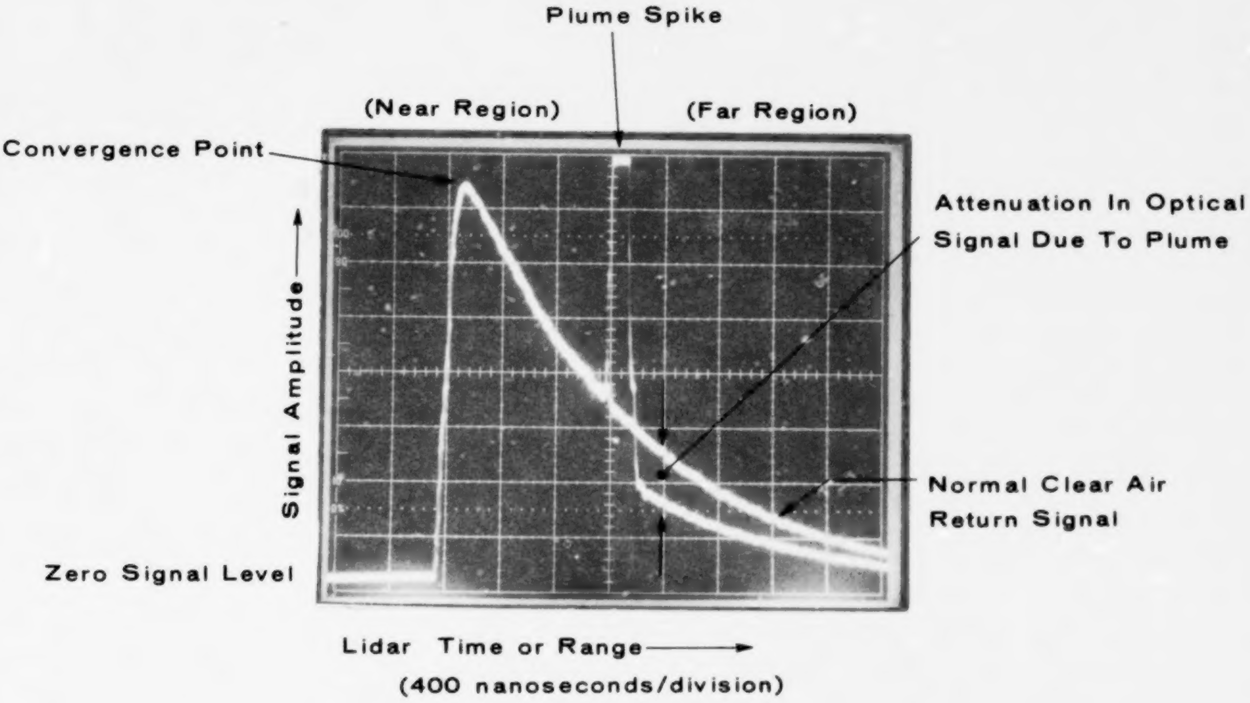
The linear video signal[37,38] is fed into one input channel of the Biomation 8100 Fast Transient Recorder (digitizer) which samples the signal at discrete time intervals and converts these samples to a series of digital numbers or words [Figure V-1]. This digital video signal or waveform is then displayed on the Tektronix R475 oscilloscope.

Photographs of the oscilloscope showing typical linear channel data in an A-Scope format are provided in Figures V-2 and V-3. In the A-scope format, the ordinate of the display is lidar signal amplitude and the abscissa is time or range (lidar range = speed of light · time/2).



Note: The convergence point is about 1250 nanoseconds from system trigger, and 540 nanoseconds from t_o.

Figure V-2 Linear Channel Video (Atmospheric Backscatter) Signal For Clear Air, Uncorrected For $1/R^2$ (Optical Generator).



Note: This oscilloscope photograph is a double exposure showing clear air signal coincident with the plume signal.

Figure V-3 Linear Channel Video Signal, 20% Opacity (Uncorrected For $1/R^2$) (Optical Generator)

The photo in Figure V-2 is a linear channel return signal for clear air. This return was generated with the optical generator used for system calibration [Figure V-1]. Several features of the return [Figure V-2] are of interest. The system trigger occurs when the Pockel-Cell Q-Switch in the laser's optical train is activated. At this point the Biomation fast transmit recorder starts sampling and digitizing the return signal. The time-zero value, t_o, is defined as the time when the laser pulse emerges from the up-collimator and is the time reference for all lidar range measurements. Lidar range measurements are calculated from the time required for the laser pulse to travel from the laser to the target in question and the backscattered light to return to the lidar receiver. The PMT output signal amplitude remains at the zero-signal level from system trigger until the transmitter-receiver convergence point [Figure IV-3], when the laser pulse enters the receiver's field of view. For the Omega-1 Lidar, t_o has been measured to be 710 nanoseconds after the system trigger, and the transmitter-receiver convergence distance is adjusted for 80 meters from the lidar, or 540 nanoseconds from t_o and 1250 nanoseconds from the system trigger.

The oscilloscope photograph shown in Figure V-3 is a linear channel return signal (A-scope) resulting from the encounter of the laser pulse with a particulate plume whose opacity is 20%. The departure of the return from clear air, due to the plume encounter, is depicted in this photograph. However, the signal is still linear and decreases or decays in amplitude, both before and after the plume, as $1/R^2$ (Eq IV-1).

The amplitude of these signals [Figures V-2, V-3] is determined by the high voltage value applied to the PMT detector and by the Biomation's input signal voltage controls. The output of the Biomation unit, displayed on the oscilloscope, is comprised of 2048 equal range or time cells along the horizontal axis of the two-dimensional display and 256 digital amplitude counts along the vertical axis. The Biomation unit has an inherent resolution of 1 part in 256 or 0.4%. The time uncertainty is less than 2 nanoseconds.

The performance evaluation results for the linear channel are given in Section VI of this report.

Logarithmic Channel

The major utility of the logarithmic channel is the quantitative measurement of high-plume opacities in the range of 50 to 100%, especially in urban areas where the ambient particulate burden or level is high, resulting in a large range of optical backscatter signal amplitudes. This channel is employed where this high signal dynamic range requirement is present.

In this channel, the linear input signal from the PMT is fed directly into a logarithmic amplifier. The output signal from this amplifier is a logarithmic function of the linear input signal. This amplifier deamplifies (gain <1) large amplitude lidar return signals while amplifying small amplitude signals (gain >>1). In summary, the logarithmic channel provides a much greater overall dynamic range within the lidar's signal processing electronics. It also extends the spatial range over which plume opacity can be effectively measured with the lidar due to the large amplification of the low-level near-region and far-region backscatter signals.

The logarithmic amplifier, manufactured by Aertech (Model LDN-1000-1), has an overall dynamic range of 100 dB* with an inherent error (linearity) of less than ±1.0 dB. The performance evaluation results for the logarithmic channel are given in Section VI.

Figure V-4 shows a logarithmic channel video signal resulting from a laser pulse propagating through a plume of 85% opacity. The characteristics of this photograph are basically the same as those for the linear channel [Figure V-3]. However, the signal level at the convergence point is much less than (nearly half) the same respective point in Figure V-3.

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* *dB = decibel, a unit of the ratio of two power or intensity values,*

$$dB = 10 \log_{10} \frac{I_1}{I_2}$$

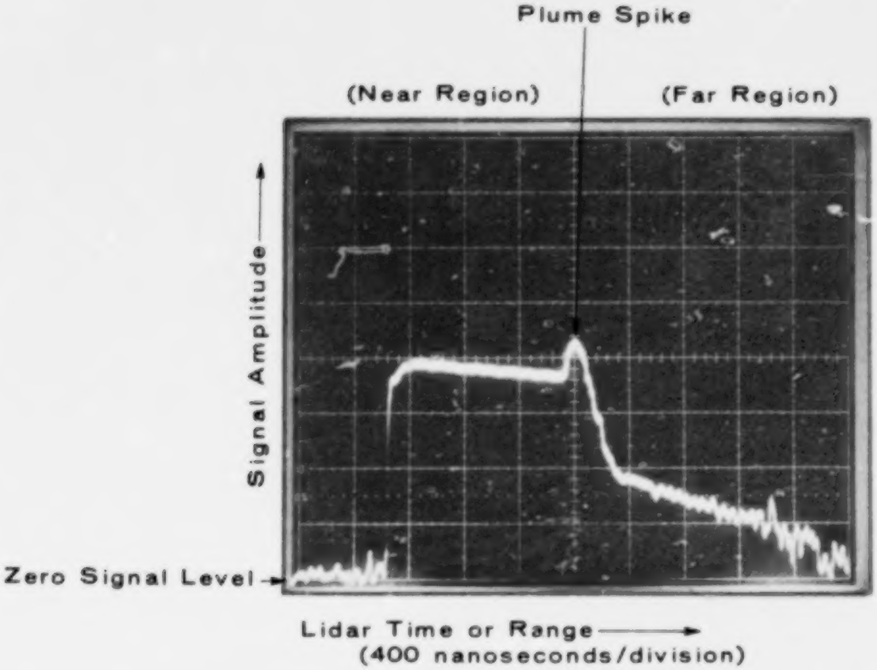


Figure V-4 Logarithmic Channel Video Signal, 85% Opacity (Uncorrected For $1/R^2$) (Optical Generator).

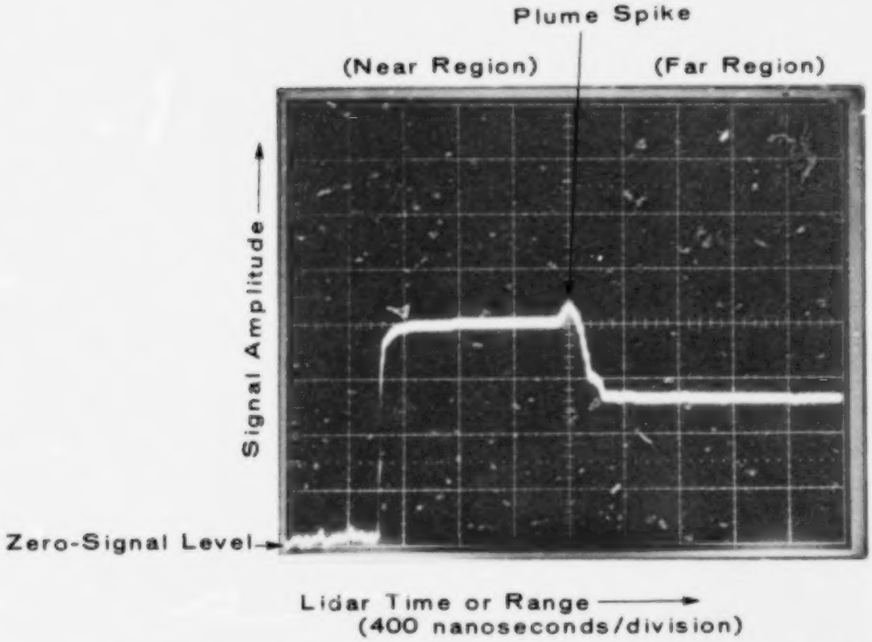


Figure V-5 Logarithmic Channel Video Signal, 85% Opacity (Corrected For $1/R^2$) (Optical Generator).

The signal level beyond the plume spike (in range) would be near zero in the linear channel. In the logarithmic channel, the signal is much greater in amplitude. The $1/R^2$-corrected signal derived from Figure V-4 is shown in Figure V-5.

As with the linear channel, the amplitude of the logarithmic channel signals is controlled by the high voltage applied to the PMT and by the Biomation unit's input signal voltage controls. The output of the Biomation unit, displayed on the oscilloscope, is comprised of 2048 range or time cells (uncertainty less than 2 nanoseconds) along the horizontal axis of the two-dimensional display. There are 256 digital amplitude counts along the vertical axis with a resolution of 1 part in 256 or 0.4%.

Since there are 256 counts in amplitude, and dynamic range of the logarithmic amplifier is 100 dB, the value of each digital count in the logarithmic channel is 0.39 dB.

The logarithmic function, being nonlinear in nature, does not represent the same relative opacity value for a given signal drop, throughout the opacity range from 0 to 100% as given in the linear channel. The function is plotted in Figure V-6. The value of each digital count (0.39 dB) represents a greater opacity difference at lower values than at higher values. This is more easily seen in Figure V-7. This figure shows the magnitude of the effect of ±1 digital count as a function of plume opacity. At 10% opacity the count error could be ± 4%, at 50% it could be about 2%, and at 80% it could be about 0.9%.

With the magnitude of the error of ±1 digital count established in Figure V-7 as a function of plume opacity, it is noteworthy to assess the effect of this error upon the logarithmic channel's ability to quantitatively measure plume opacity.

Referring to Figure V-7, the digital count (bit) error magnitude is plotted as a function of plume opacity for the logarithmic and the linear

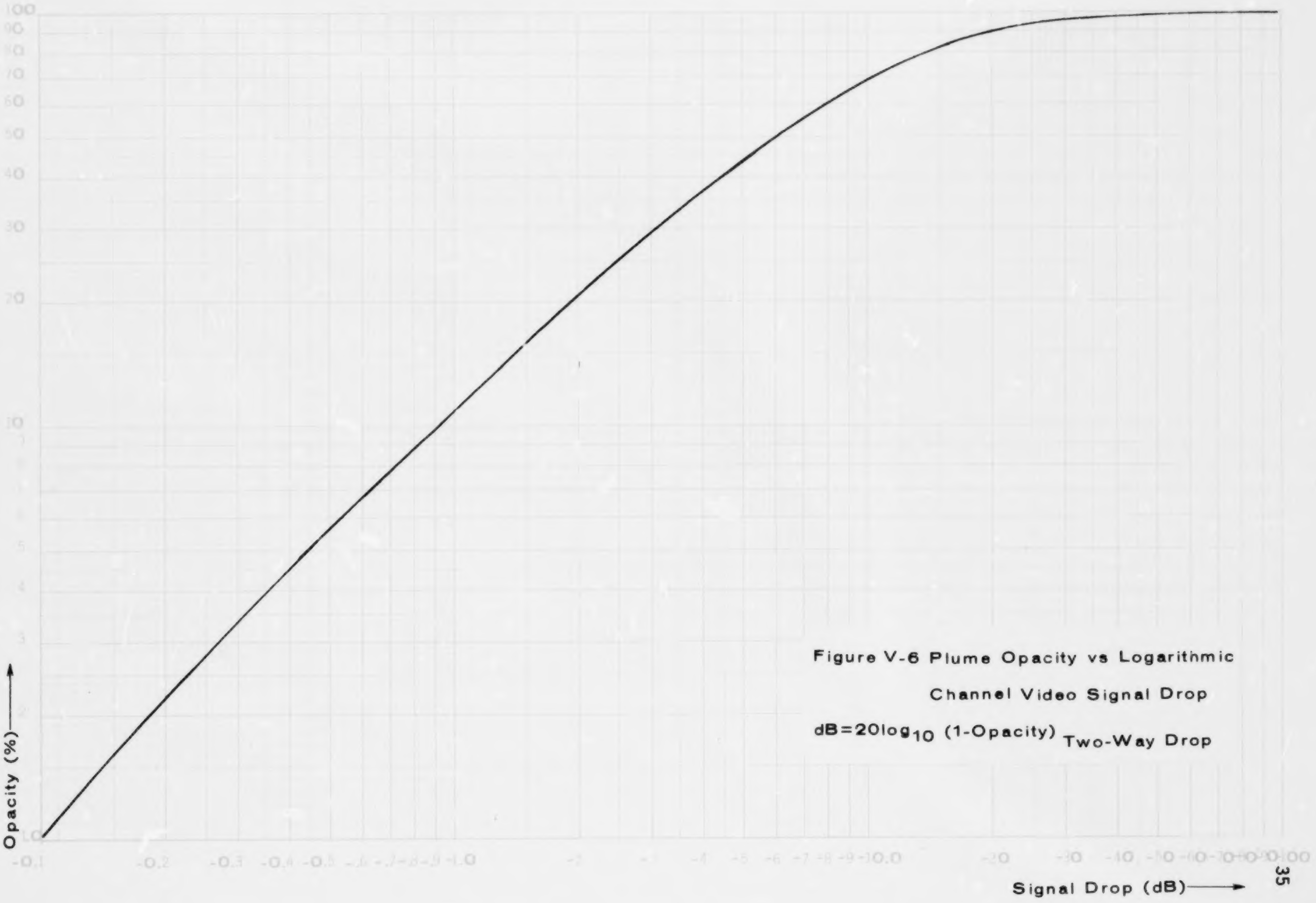


Figure V-6 Plume Opacity vs Logarithmic Channel Video Signal Drop

$dB = 20\log_{10}(1 - \text{Opacity})$ Two-Way Drop

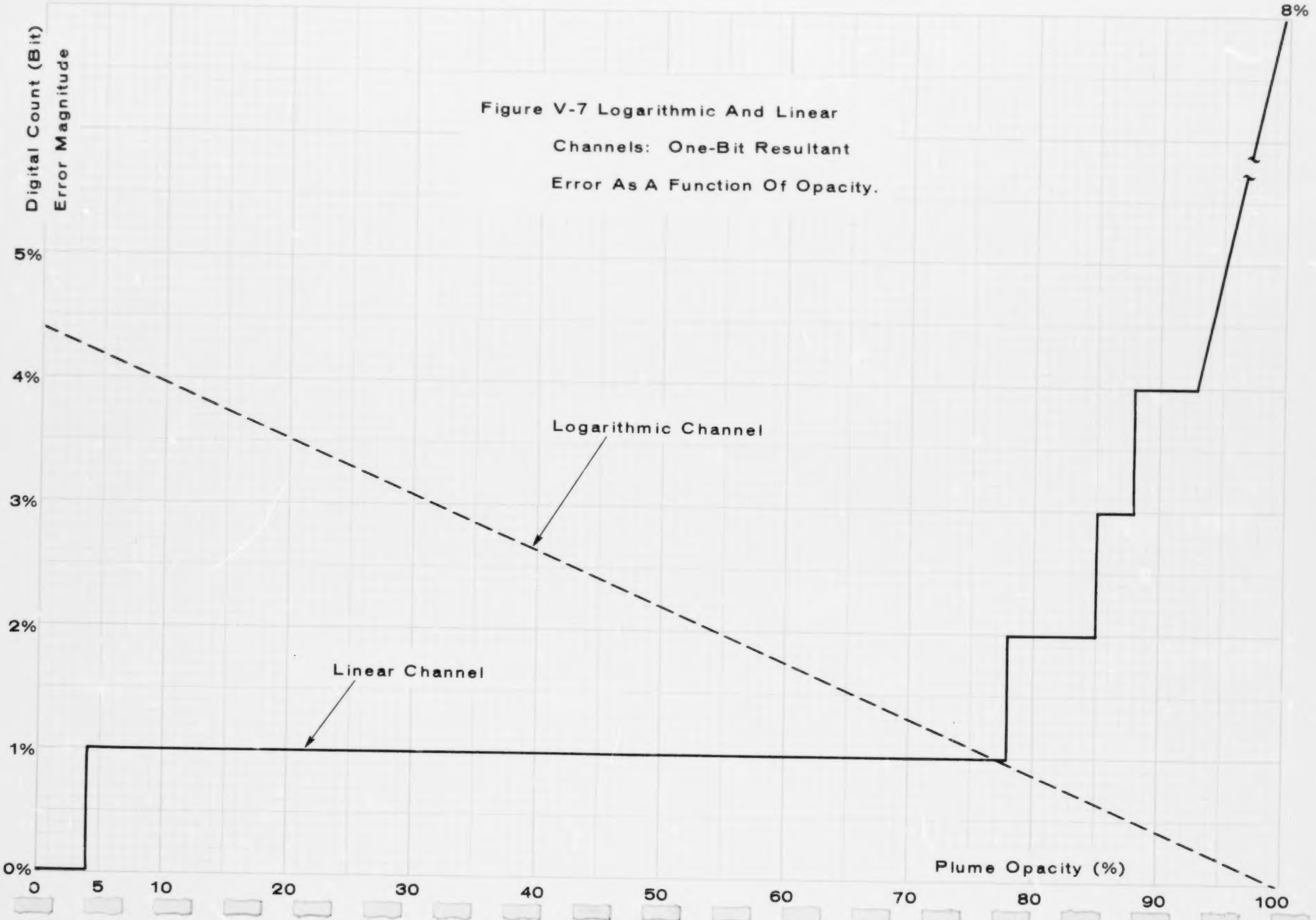


Figure V-7 Logarithmic And Linear Channels: One-Bit Resultant Error As A Function Of Opacity.

channels. For the linear channel, the count error is zero from 0 to 4% opacity. It is rounded (to the nearest percent) up to 1% from 4 to about 55%. It is 1% from 55 to 78%. From 78 to 100% the count error magnitude increases from 1 to 8%, as shown in the figure. This effect can be understood by referring to the oscilloscope photographs in Figures V-8 and V-9, and then comparing them with the logarithmic channel photographs in Figures V-4 and V-5.

In Figure V-8, which is a linear channel oscilloscope photo of an 85% opacity plume (approximate) uncorrected for $1/R^2$, the signal level is nearly zero in the far region (behind the plume). Figure V-9 shows the same return corrected for $1/R^2$. The signal in the far region remains near zero even after correction.

Comparing the logarithmic and linear video signals, corrected for $1/R^2$, there is a significant difference in signal levels in the far region [Figures V-5 and V-9]. To be more quantitative, if the near-region signal is 140 digital counts above zero signal level in both channels, then for 85% plume opacity the signal level is 3 digital counts above the zero-signal level for the linear channel and 88 digital counts for the logarithmic channel. A change of about ±1 digital count in the linear channel at this opacity value represents a 33% adjustment of the total signal level in the far region while the effect of the count error on this signal level is only about 1% in the logarithmic channel. This is graphically portrayed in Figure V-7.

The effect of the ±1 digital count error is kept to a minimum by having the Biomation (digitizer) unit factory-calibrated once per year.

Depending upon the magnitude (signal amplitude) of the near-region portion and the particulate plume optical backscatter signals, the electronics system has a detector gain modulation (gating) scheme that is used to suppress these signals to levels within the operating range of the PMT detector and the Biomation Fast Transient Recorder. The scheme consists of two independent electronic gates that are continuously variable in lidar-range and also continuously variable over an amplitude range of 0 dB to -42 dB (typical).

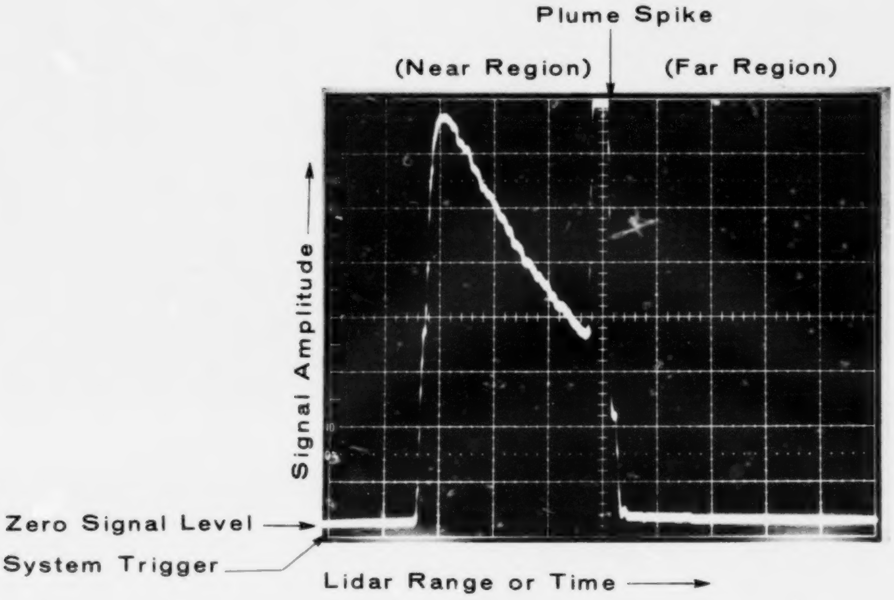


Figure V-8 Linear Channel Video Signal, 80% Opacity (Uncorrected For $1/R^2$) (Optical Generator)

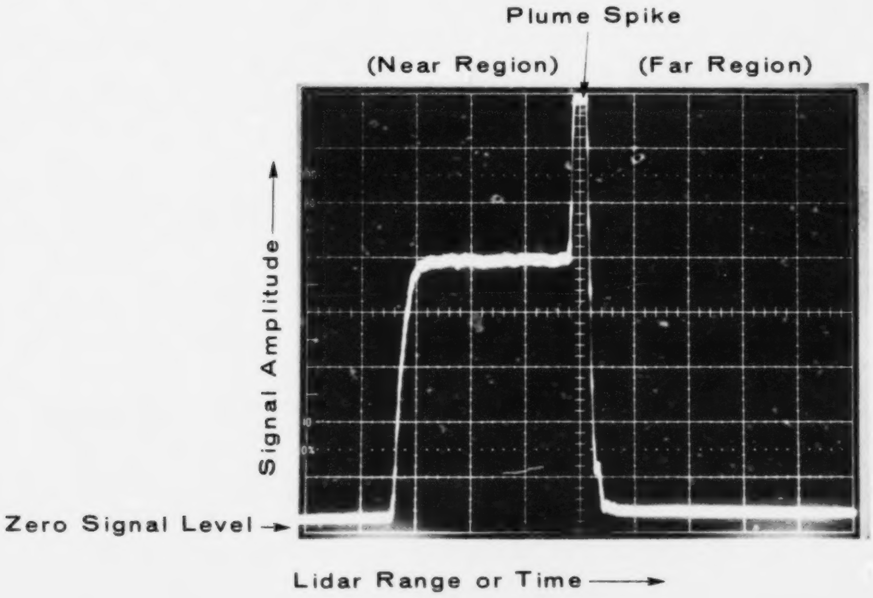


Figure V-9 Linear Channel Video Signal, 80% Opacity (Corrected For $1/R^2$) (Optical Generator)

If the plume spike is quite high in the video signal (such as reflectance from a white-dense plume), then gate-2 can be positioned over that portion of the backscatter signal, and the amount of signal (electronic) suppression desired can be manually incorporated into the PMT detector. The detector is capable of operating with extremely large variations of signal amplitude; however, the plume spike signal saturates the Biomation (digitizer) unit as is indicated by the clipped or flat signal at the top of the oscilloscope display in Figure V-9. The shape of this signal is lost due to the clipping. The shape and magnitude of the upper portion of the spike can be retained by using gate-2 as shown in Figure V-10.

In like manner, gate-1 can be used to suppress the near-region backscatter signal to any desired level from 0 dB to -42 dB. The strong near-region signal usually comes from using the lidar in local atmospheric conditions of heavy particulate burden. Figure V-11 shows the effect of gate-1 suppression upon the near region signal. The amount of suppression in each gate is measured in a quantitative manner. Depending upon the use of the data, the suppression magnitude must be taken into account during data processing.

If overall signal suppression or attenuation is required, i.e., in the near- and far-regions and for the plume spike, optical neutral density filters are available in the lidar for this purpose. The neutral density (gray, transparent) filter is installed in the receiver's optical path just ahead of the PMT detector. The amount of attenuation provided by each filter is as follows:

Table V-3

OPTICAL DENSITY VS OPTICAL TRANSMITTANCE

Filter No.	Optical Density[a]	Optical Transmittance (%)	Effective Signal Drop (dB)
1	1.0	10	10
2	2.0	1	20
3	3.0	0.1	30
3+1	4.0	0.01	40

[a] Optical Density: $D = -\log_{10}$ (transmittance)

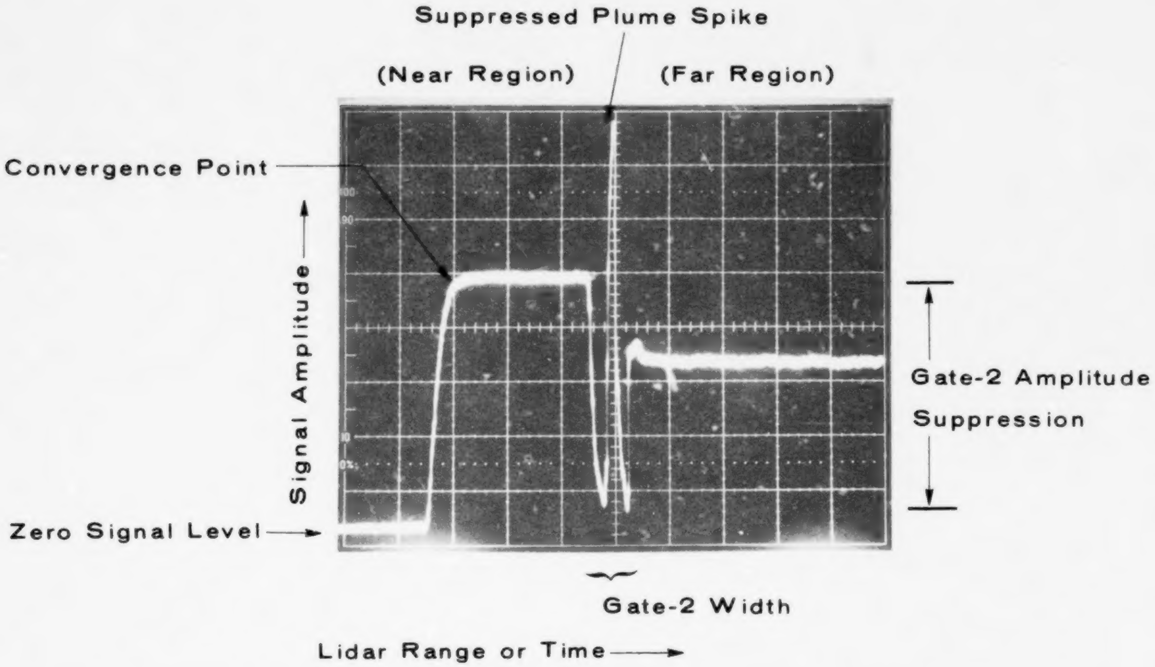


Figure V-10 Suppressed Plume Spike, Linear Channel Video Signal, 20% Opacity (Corrected For $1/R^2$), Gate-2

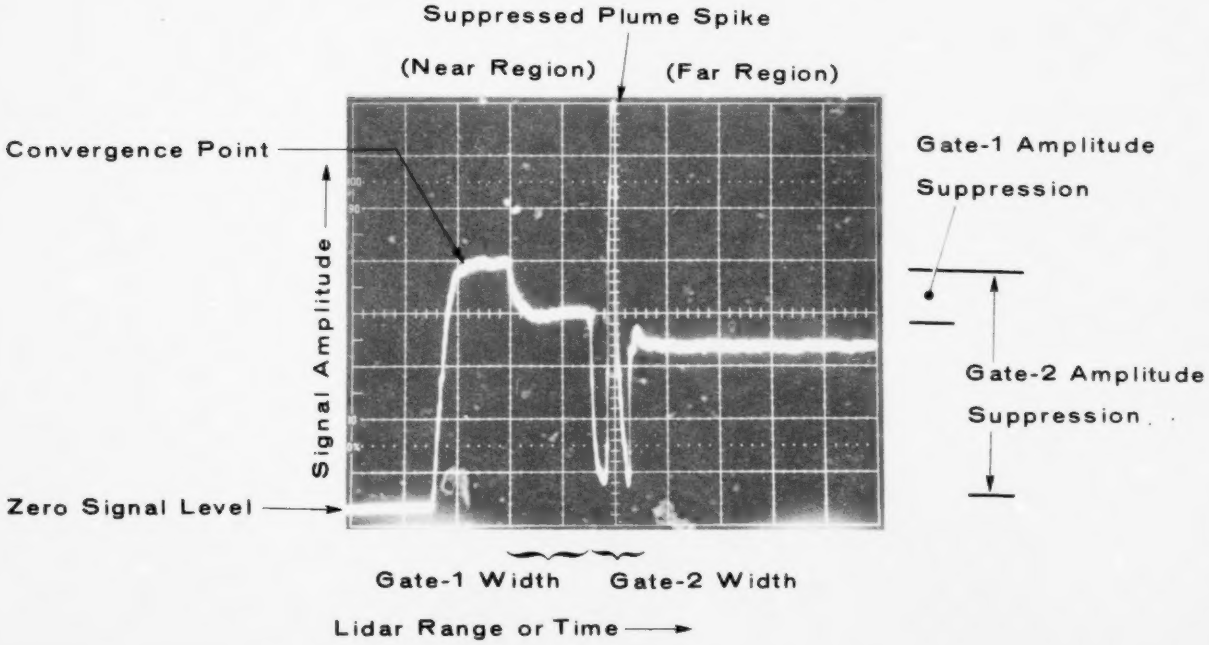


Figure V-11 Suppressed Plume Spike And Near-Region Signal, Linear Channel Video Signal, 20% Opacity (Corrected For $1/R^2$), Gate-1 And Gate-2

As mentioned above, the Biomation 8100 Fast Transient Recorder converts the output signal of the PMT from analog to digital (computer compatible) form and saves it in an internal memory. This stored signal is available in analog form to the Tektronix R475 oscilloscope and in digital form to the Hewlett Packard 9825A computer.

The computer has 22,952 bytes (11476 16-bit words) of user addressable read/write memory, a 32-character light emitting diode (LED) display, a 16-character thermal strip printer, two-track cartridge tape drive, three input/output (I/O) slots for interfacing peripheral equipment, four plug-in read-only memory (ROM) slots, and a versatile keyboard. The read-only memory units provided with the HP 9825A in the Omega-1 lidar are the general I/O-extended I/O, plotting, and string-advanced programing. The general I/O-extended I/O ROM adds the instruction set necessary to command the 16-bit parallel I/O interface for the Biomation unit and the Hewlett-Packard (HP-IB) interface bus for the digital clock (year, date, hour, minutes, second), the external 9-track tape drive, and the analog to digital converter. This ROM also permits the fastest practicable data transfer rates. The string-advanced programing ROM adds instructions for the fastest data manipulation and computation modes of this computer.

This computer has a two-track cartridge tape drive (using specialized cassettes) and has a recording capacity of 256,000 bytes per cartridge. This device is used to read in computer software used for data flow management, data recording (alternate), and opacity calculations. It is also used in editing, revising, and recording computer software.

The primary lidar data recording mechanism is a Kennedy Model 9800 digital tape transport which is interfaced with a Dylon Model 1015A magnetic tape controller/formatter. The data density on the tape is 800 bits-per-inch (9 track). Data recording speed is 25 inches-per-second (ips). The tape drive/formatter combination is an NRZI ANSI standard system which is compatible with EPA-NEIC's PDP-11-70 laboratory computer system, used for data processing.

The tape drive uses 8.5-inch-diameter tape reels, and the tape is 1,200 feet in length and 0.5 inches wide. About 1,850 lidar backscatter signals along with individual data blocks and file marks can be recorded on each tape reel. The tape drive is connected to the lidar's HP 9825A computer through the IEEE-488-1975 general purpose interface bus. The tape drive is capable of sustained data rates in excess of 15,000 characters-per-second.

The individual data block, recorded on magnetic tape for each and every lidar backscatter signal, is comprised of the following:

- Month, day, year that the lidar shot was recorded
- Time of signal to the nearest second (hour, minute, second)
- Location of data on tape (file number)
- Two 32-character identification blocks for each source under-test
- Biomation unit's sampling interval (nanosec/point)
- Biomation unit's input voltage range
- Video channel identification (linear or logarithmic)
- Location on tape for the reference (clear air) signal or measurement
- Azimuth and elevation angles of the transmitter/receiver's instantaneous field-of-view with respect to the localized vertical and horizontal axes, which the computer obtains directly from the mount via an analog/digital converter
- Amount of signal suppression selected by the lidar operator for each of the two gates as discussed previously

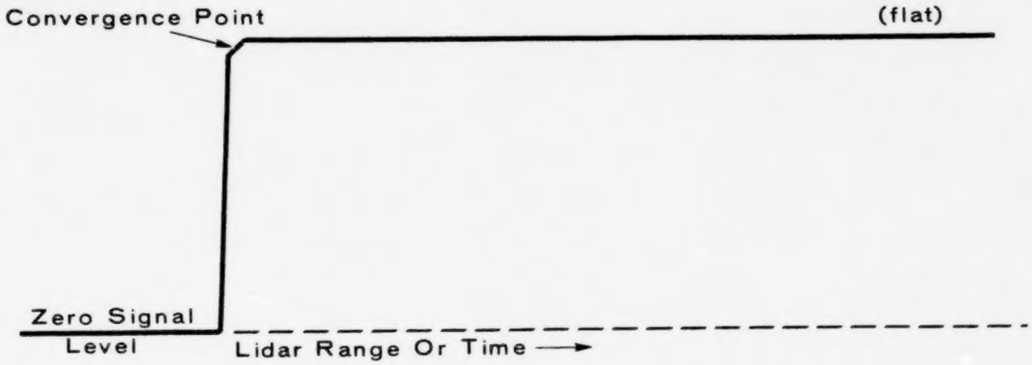
The cartridge tape drive in the lidar computer may be used as an alternate data recording mechanism. However, each tape cartridge holds only 120 lidar backscatter signals on two separate tracks.

The basis for calculating opacity from lidar A-scope data is discussed in Section IV. In the actual field environment, the ideal condition is rarely encountered. If the lidar were fired into the local atmosphere in any urban area, the $1/R^2$ corrected (compensated) signal would not be flat as shown in Figure V-12(a). The signal realistically would exhibit a slight negative or downhill slope [Figure V-12(b)] which is due to attenuation (optical extinction) of the laser beam as it propagates through an atmospheric path containing ambient particulates and water vapor or humidity. The magnitude of the atmospheric attenuation increases with lidar range.

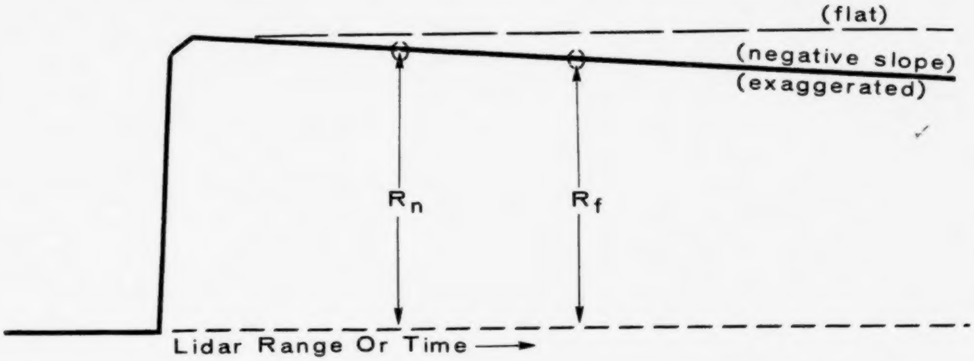
The sketch of a lidar return signal through a smoke plume [Figure V 12(c)] shows that the backscatter signals from the near-region and the far-region also exhibit the negative slope. Since the signal segments are not horizontal, the opacity calculation would be dependent upon the points along the signal traces at which the near-region and far-region signal segments are sampled or measured by the computer. This range dependence upon the magnitude of the backscatter signal segments is undesirable.

In the Omega-1 Lidar, the effects of the signal's negative slope due to atmospheric attenuation are greatly reduced and, much of the time, eliminated by periodically making a reference measurement (ambient air signal) along a line-of-sight near, but not including, the particulate plume. The reference measurement is used to normalize the smoke plume A-scope signal in the computer. Thus the near-region and the far-region signal segments are rendered flat and the range dependence, mentioned above, is greatly reduced or eliminated. (The reference measurement will remove any systematic anomaly in the electronics of the lidar such as a nonlinearity. Such an anomaly is usually due to degradation within a piece of analog electronics or within the detector.) Comparison of the processing of lidar data, with and without the reference shot, has shown that an opacity calculation error of as much as ±1 to ±3% can result by not using the reference measurement, depending upon the amount of particulate loading along the lidar's line-of-sight.

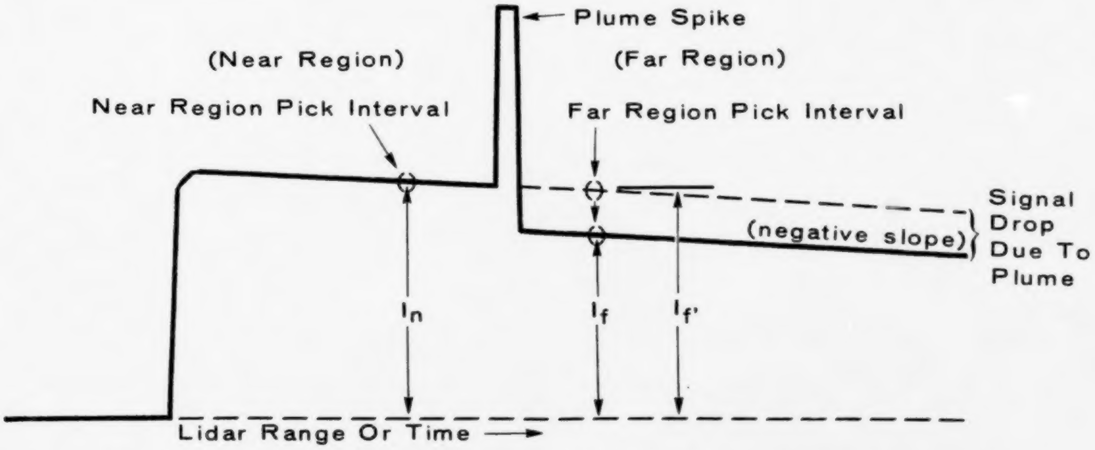
In order to take the reference measurement [Figure V-12(b)] into account in the opacity calculation, the computer carries out several functions as follows [Appendix B(1) for Lidar Computer; Appendix B(2) for Laboratory Computer]:


Convergence Point
(flat)
Zero Signal
Level
Lidar Range Or Time →

(a) Ideal clear air signal, $1/R^2$ corrected,


(flat)
(negative slope)
(exaggerated)
R_n
R_f
Lidar Range Or Time →

(b) Reference measurement made near the plume in order to account for the prevailing non-ideal atmospheric conditions, $1/R^2$ corrected,


Plume Spike
(Near Region)
(Far Region)
Near Region Pick Interval
Far Region Pick Interval
Signal Drop Due To Plume
(negative slope)
I_n
I_f
$I_{f'}$
Lidar Range Or Time →

(c) Lidar return signal showing the effects of high atmospheric attenuation upon the near region and far region segments, $1/R^2$ corrected.

Figure V-12 Sketches Of Lidar A-Scope Backscatter Signals

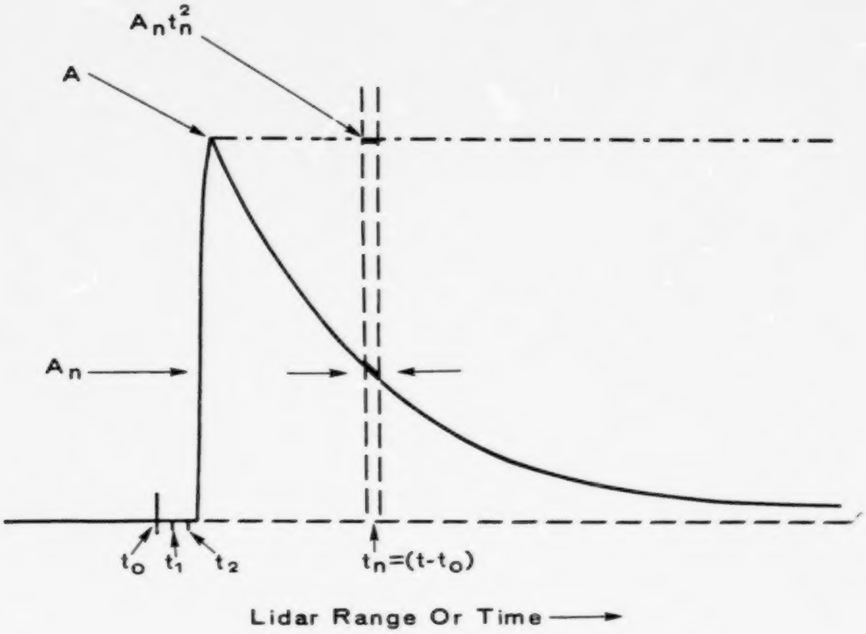
1. $1/R^2$ Correction Mechanism

The computer performs the $1/R^2$ range correction on both the reference and the plume data (video) signals. The $1/R^2$ correction mechanism is depicted in Figure V-13. The uncorrected digital signal is comprised of many short segments or time intervals. The length of these time intervals, previously called the sample interval, is selected on the Biomation unit by the operator. The size of the sample interval (each repetitive time interval) is usually 10 nanoseconds.

Each time interval (t_1, t_2, ...t_n...) in the digital signal, beyond or later in time than t_0, is subjected to the $1/R^2$ correction. The signal amplitude, A_n, of the nth time interval is multiplied by the square of the time, elapsed from t_0, defining that interval. In Figure V-13, the uncorrected signal amplitude, A_n, is multiplied by the square of the time of the nth interval, t_n, yielding $A_n t_n^2$, the corrected amplitude. This process is carried out for each time interval in the backscatter signal producing the $1/R^2$ corrected signal.

2. Pick Interval Selection

The computer receives the "pick" or "sampling" points either automatically from the software or as manual commands from the lidar operator entered on the computer's keyboard. A pick point is the beginning of a time (or range) interval, which is called a pick interval, 100 nanoseconds (50 ft, 15 m) in length. Two such pick intervals must be specified, one in the near-region, I_n, and one in the far-region, I_f, of the A-scope signal [Figure V-12(c)]. These pick intervals apply to both the reference and the plume data signals.


$A_n t_n^2$
A
A_n
t_o
t_1
t_2
$t_n=(t-t_o)$
Lidar Range Or Time →

$A_n t_n^2 < A^2$ due to atmospheric extinction

$$R=ct/2, \quad R^2=c^2t^2/4,$$

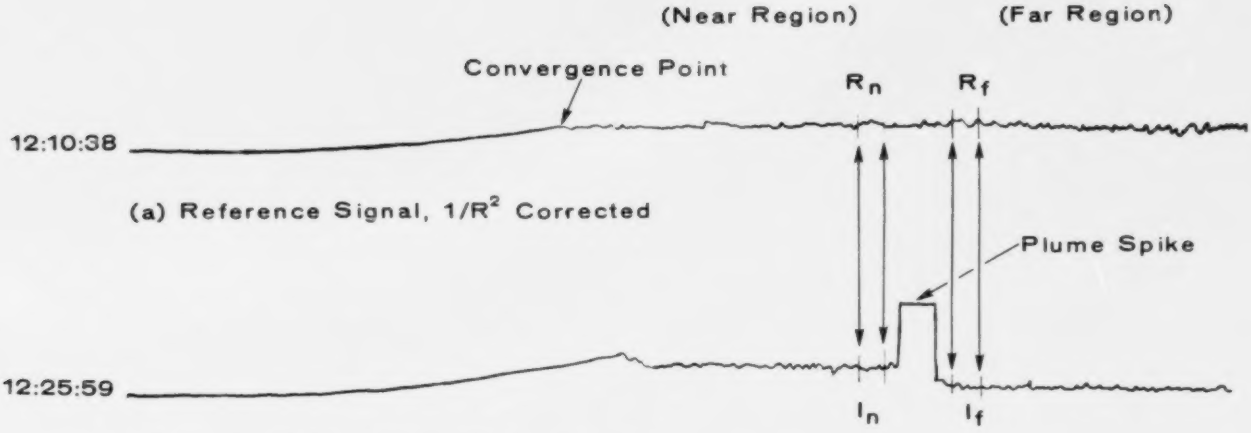
$$(1/R^2)\cdot R^2 = \frac{1}{\frac{c^2t^2}{4}} \cdot \frac{c^2t^2}{4} = (1/t^2)\cdot t^2 = 1$$

Figure V-13 $1/R^2$ Correction Mechanism

The criterion for the manual selection of the pick points is described in the following examples. Figure V-14 gives 3 actual lidar video return signals which were computer plotted. Figure V-14(a) is the $1/R^2$-corrected clear air reference video signal recorded for use in calculating the plume opacity from the plume return video signal [Figure V-14(b)]. These signals contain slight atmospheric backscatter noise as seen in the ripple or variations in amplitude to the right of the convergence point. The near-region pick interval, I_n, is chosen as close to the plume as practical with the signal in the chosen interval being of minimum overall amplitude and minimal amplitude variation. The reference measurement interval, R_n, must be chosen for the same time interval as I_n, as shown in Figure V-14 (a,b).

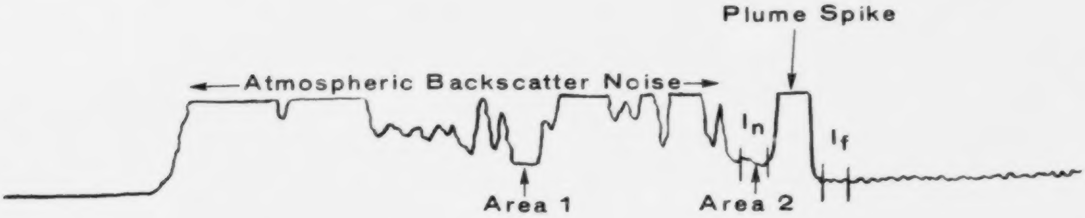
The far-region pick interval, I_f, is also chosen as close to the plume as practical. The video signal in this chosen interval is of minimal amplitude variation and minimum overall amplitude. The far-region reference measurement interval, 0_f, must be chosen over the same interval I_f [Figure V-14 (a,b)].

Figure V-14(c) is a computer plot of a lidar video signal showing significant levels of atmospheric backscatter noise in the near region. In this case there are only two areas in this region where the pick interval can be selected, i.e., 1 and 2 as shown. The average signal amplitude over the 100-nanosecond interval in each of these two areas is the same. However, in applying the above-mentioned criterion, area 2 is the one to be used for the opacity calculation (the respective reference measurement is not shown). The far-region video signal amplitude, I_f, is chosen as shown in Figure V-14(c), according to the criterion. Any desired pick interval, such as 1 and 2, [Figure V-14(c)] that is not 100 nanoseconds wide cannot be used in the opacity calculation. If no such interval exists in the near-region or the far-region, the plume data signal cannot be used for the opacity calculations and is discarded.



(a) Reference Signal, $1/R^2$ Corrected

(b) Plume Data Signal, $1/R^2$ Corrected



(c) Plume Data Signal, $1/R^2$ Corrected

NOTES: (1) Minimum distance from convergence point to the plume spike is 50 meters.
(2) All pick intervals are 100 nanoseconds wide.

(a) Clear Air Reference Video Signal, $1/R^2$-Corrected, showing slight atmospheric noise. This reference signal is for (b). R_n, R_f are chosen as indicated coincident with I_n, I_f.

(b) Lidar-return Video Signal, $1/R^2$-Corrected, showing slight atmospheric noise, plume spike and the decrease in atmospheric backscatter signal level in the far region due to the opacity of the plume encountered. I_n, I_f are chosen as indicated.

(c) Lidar-return Video Signal, $1/R^2$-Corrected , showing significant atmospheric noise in the near region, plume spike, minimal noise in the far region and the decrease in far region signal level due to the opacity of the plume encountered. I_n, I_f are chosen as indicated.

Figure V-14. Computer Plots of Lidar A-Scope Backscatter Signals

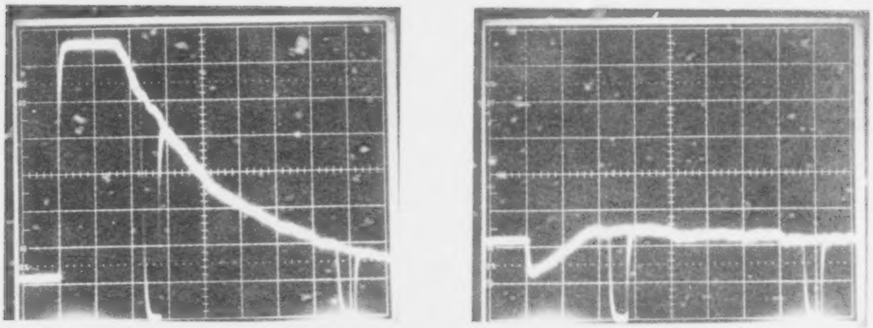
Various examples are provided in Figures V-15 through V-20 which demonstrate the selection of the best pick intervals. Figure V-15 shows A-scope photos for reference signals and Figures V-16 through V-20 are A-scope photos for plume data signals.

The first step in the automatic selection [Appendix B(b)] of the near- and far-region pick intervals is to divide the plume data signal amplitude by the reference signal amplitude at the corresponding time intervals (t_n), to obtain a "normalized" signal,

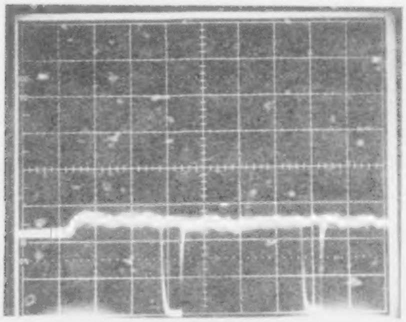
$$\frac{\text{plume data signal amplitude } (t_n)}{\text{reference signal amplitude } (t_n)} = \text{normalized signal } (t_n).$$

The pick intervals, selected using this normalized signal, are 100 nanoseconds (15 meters) in length and consist of at least five contiguous sample intervals. The following criteria, given in order of importance, govern the pick interval selection process: (1) The near- and far-region pick intervals shall be in a region of the normalized signal where the reference signal fulfills the requirements given earlier in this section, and are everywhere greater than zero. (2) The pick intervals are selected by computer with each having minimum average amplitude. (3) If more than one pick interval is located having the same minimum average amplitude, the interval closest to the plume spike is selected. (4) The standard deviation, S_o [Equation V-15], for the calculated opacity is 8% or less.

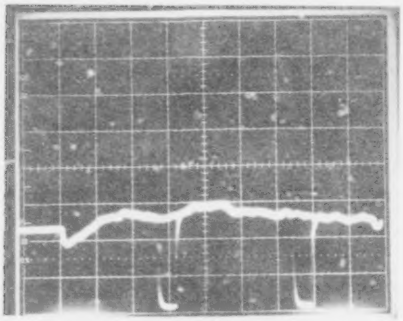
The search routine of the computer software is initialized to the near and far sides of, and adjacent to the plume spike. The routine calculates all minima in the near- and far-region of the normalized signal within the search limits selected by the data analyst and makes its selection for each region. If S_o is calculated to be greater than 8%, the far pick interval is changed to the next interval of minimal average amplitude. If S_o is still greater than 8%, then this procedure is repeated for the far pick interval. The procedure is repeated, as required, for the near



(a) No $1/R^2$ Correction (b) Photo (a)-$1/R^2$ Corrected

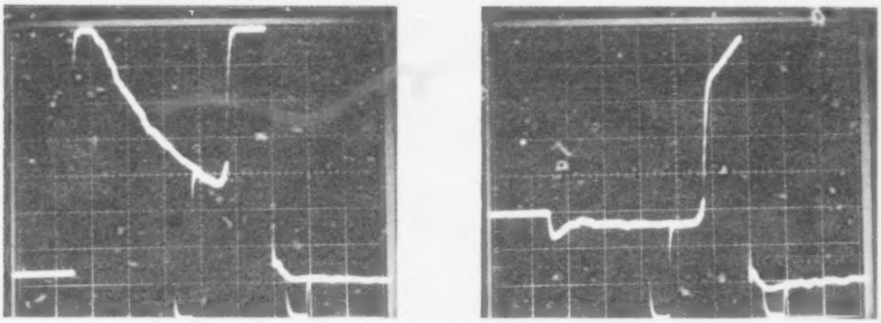


(c) $1/R^2$ Corrected



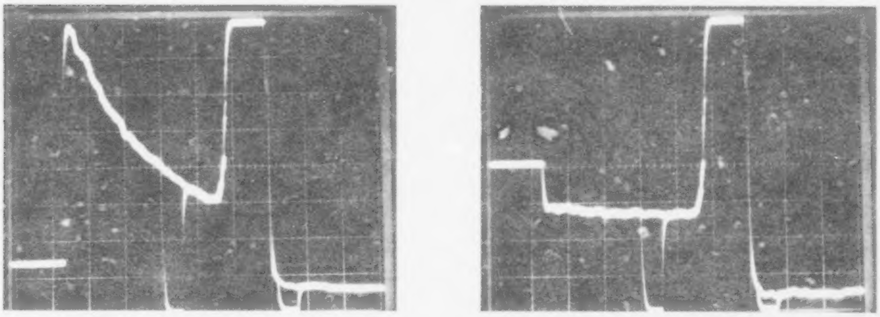
(d) $1/R^2$ Corrected

Figure V-15 Examples Of Pick Intervals - Reference Signals (Rectangular - Shaped Cursors Define Pick Intervals)



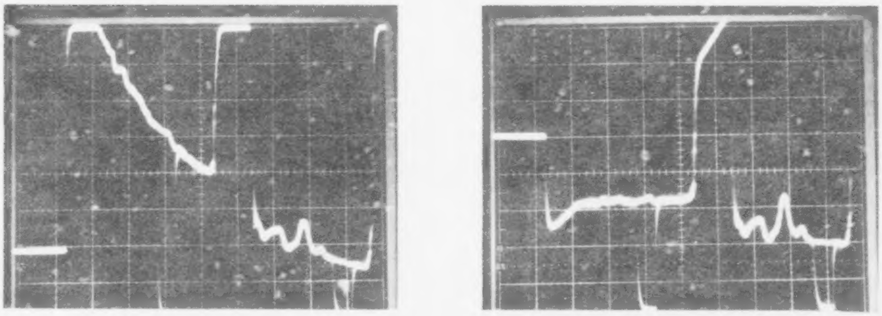
(a) No $1/R^2$ Correction

(b) Photo (a)-$1/R^2$ Corrected



(c) No $1/R^2$ Correction

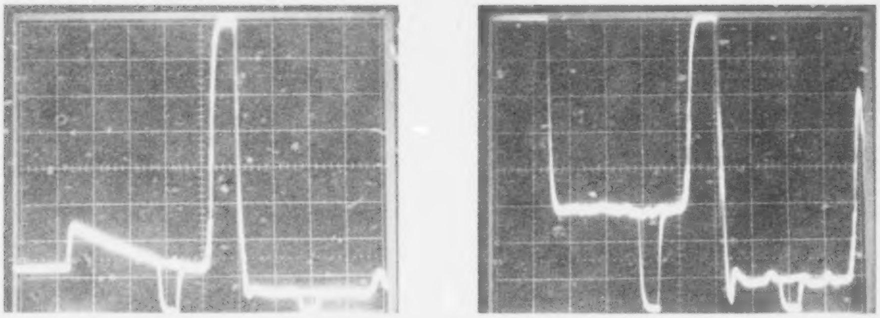
(d) Photo (c)-$1/R^2$ Corrected



(e) No $1/R^2$ Correction

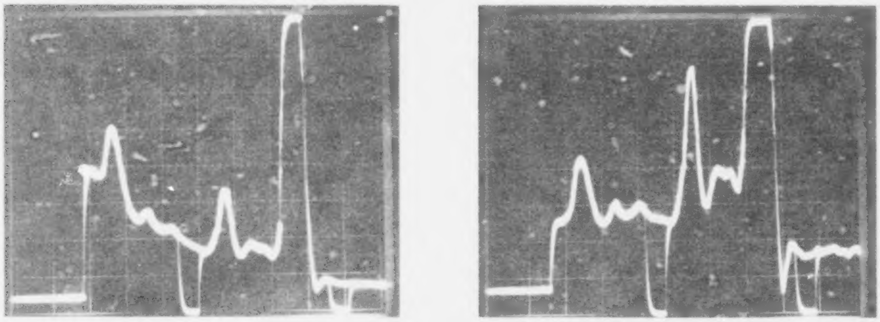
(f) Photo (e)-$1/R^2$ Corrected

Figure V-16 Examples Of Pick Intervals - Plume Data Signals (Rectangular-Shaped Cursors Define Pick Intervals)



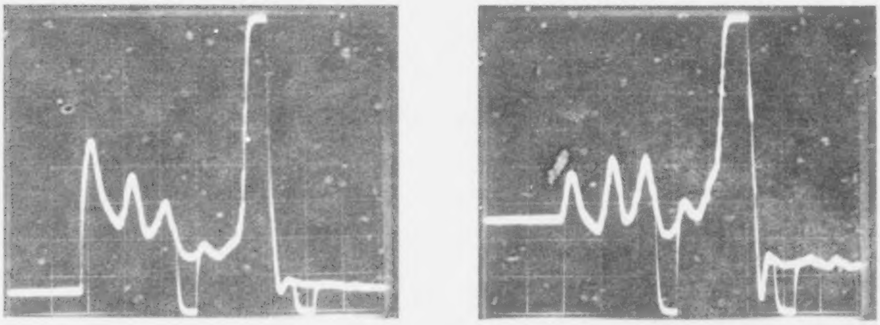
(a) No $1/R^2$ Correction

(b) Photo (a)-$1/R^2$ Corrected



(c) No $1/R^2$ Correction

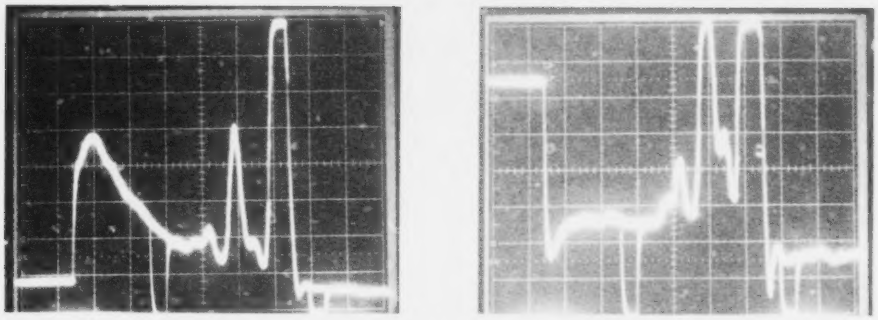
(d) Photo (c)-$1/R^2$ Corrected



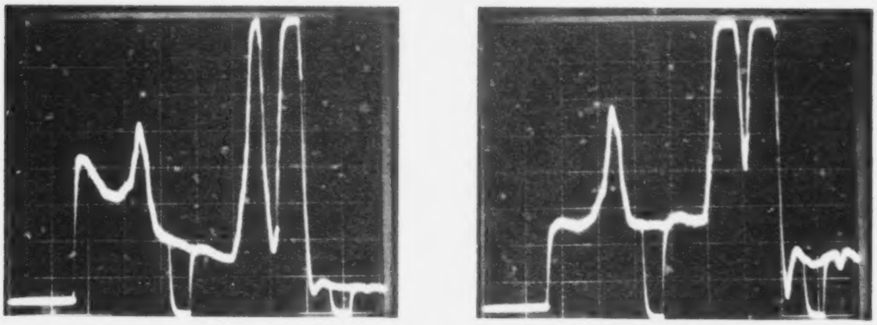
(e) No $1/R^2$ Correction

(f) Photo (e)-$1/R^2$ Corrected

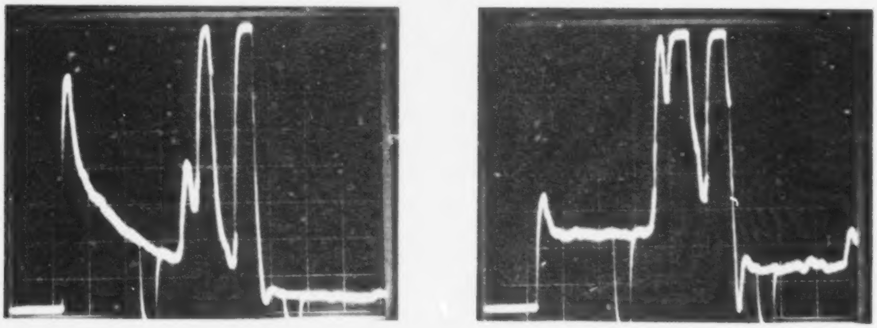
Figure V-17 Examples Of Pick Intervals - Plume Data Signals (Rectangular-Shaped Cursors Define Pick Intervals)



(a) No 1/R^2 Correction (b) Photo (a)-1/R^2 Corrected

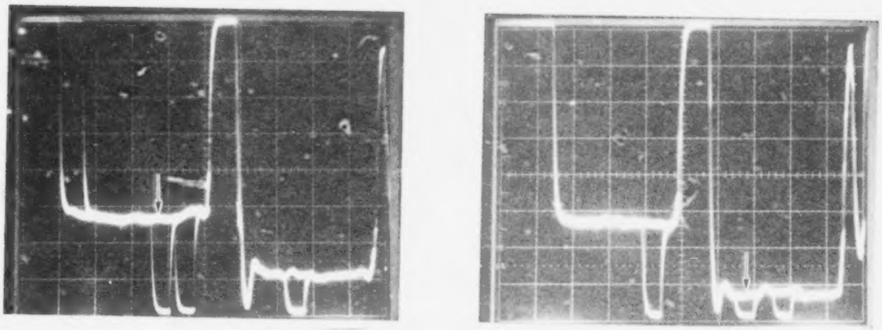


(c) No 1/R^2 Correction (d) Photo (c)-1/R^2 Corrected

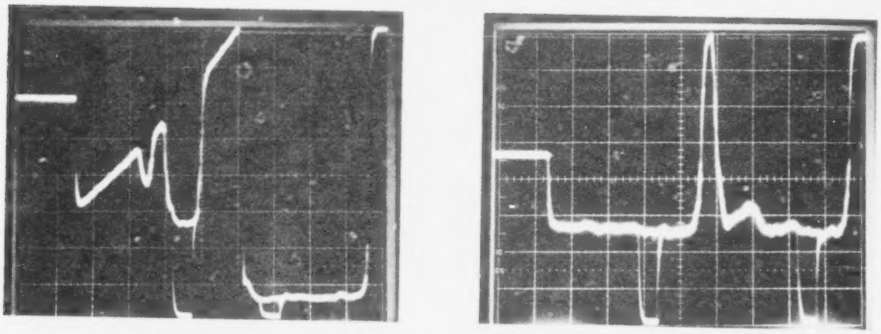


(e) No 1/R^2 Correction (f) Photo (e)-1/R^2 Corrected

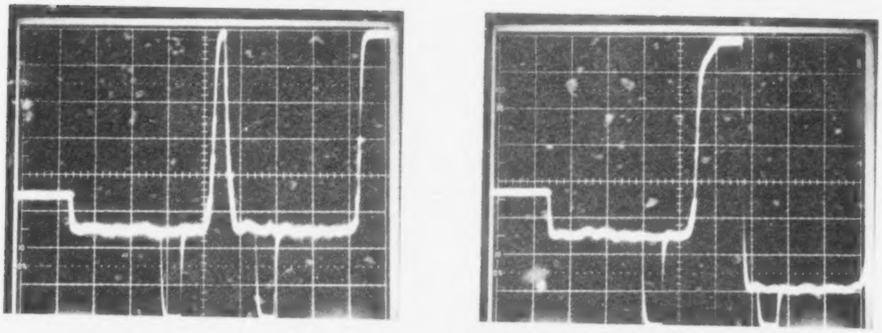
Figure V-18 Examples Of Pick Intervals - Plume Data Signals (Rectangular-Shaped Cursors Define Pick Intervals)



(a) Best Near-Region Pick Interval (b) Best Far-Region Pick Interval

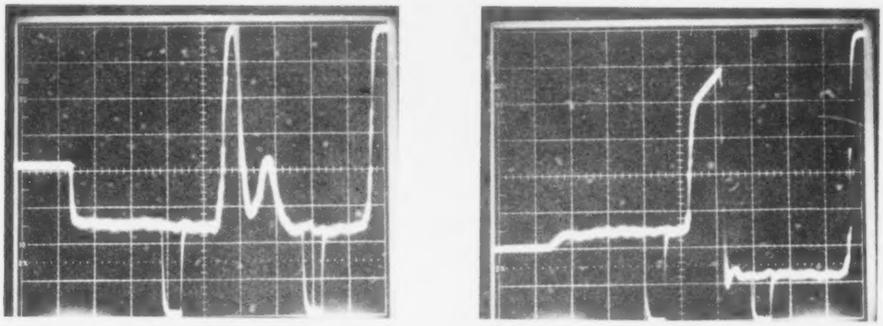


(c) Best Pick Intervals (d) Best Pick Intervals



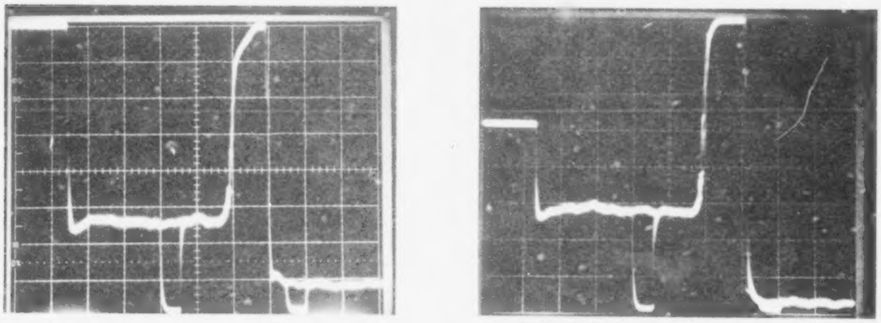
(e) Best Pick Intervals (f) Best Pick intervals

Figure V-19 Examples Of Pick Intervals - Plume Data Signals (Rectangular-Shaped Cursors Define Pick Intervals)



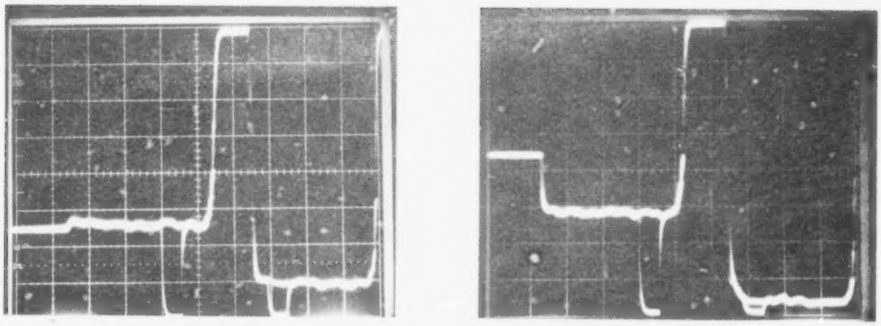
(a) Best Pick Intervals

(b) Best Pick Intervals



(c) Best Pick Intervals

(d) Best Pick Intervals



(e) Best Pick Intervals

(f) Best Pick Intervals)

Figure V-20 Examples Of Pick Intervals - Plume Data Signals
(Rectangular-Shaped Cursors Define Pick Intervals)

pick interval. If S_0 remains greater than 8%, the plume data signal is discarded. This search routine operates on the NEIC PDP 11-70 laboratory computer system in an interactive mode wherein the data analyst has the option of accepting or rejecting the automatically selected pick intervals.

3. Pick Interval Amplitude Calculation

The computer calculates the average of the amplitudes of the 10 consecutive time (or range) sample intervals (each 10 nanoseconds in length) for each of the near-region (R_n) and the far-region (R_f) signal segments within the reference signal. The R_n, R_f intervals are chosen for the same pick intervals as I_n and I_f [Figure V-14(a,b)]. The standard deviation of the 10 data points for each respective R_n and R_f is also calculated.

The computer averages the amplitudes of the 10 consecutive time sample intervals (each 10 nanoseconds in length) for each of the near-region (I_n) and the far-region (I_f) signal segments within the plume data signal. It also calculates the standard deviation of these 10 data points for I_n and I_f.

The average amplitude (I_n, I_f, R_n, R_f) of each pick interval is calculated by these equations:

$$I_n = \frac{1}{m} \sum_{i=1}^{m} I_{ni}, \qquad I_f = \frac{1}{m} \sum_{i=1}^{m} I_{fi},$$

$$R_n = \frac{1}{m} \sum_{i=1}^{m} R_{ni}, \qquad R_f = \frac{1}{m} \sum_{i=1}^{m} R_{fi},$$

where I_{ni}, I_{fi}, R_{ni}, and R_{fi} are the individual amplitudes of each respective sampling interval; m is the number of sample intervals in each pick interval (m = 10).

These calculations are performed as an integral part of the automatic pick interval mechanism for the near-and far-region ratios discussed in Item 2.

The actual opacity calculation is derived from the information given in Figure V-12. The near-region and far-region signal segment measurements are related by:

$$I_n = kR_n \tag{V-1a}$$

$$I_{f'} = kR_f \tag{V-1b}$$

where:

I_n = near-region signal amplitude, plume data signal,
I_f'= clear air equivalent signal amplitude [Figure V-12(c)], far-region,
R_n = near-region signal amplitude, reference signal,
R_f = far-region signal amplitude, reference signal,
k = a normalization factor.

The opacity measurement is related to the signal drop due to the plume [Figure V-12(c)] and is derived in the following manner:

$$0_p = 1 - \left(\frac{I_f}{I_{f'}}\right)^{\frac{1}{2}}$$

Substituting Eq (V-1b) for $I_{f'}$, Equation (V-2) becomes:

$$0_p = 1 - \left(\frac{I_f}{kR_f}\right)^{\frac{1}{2}} \tag{V-3}$$

Using the relationship $k = I_n/R_n$, [Eq (V-1a)], in Eq (V-3), the proportionality factor is eliminated, which gives:

$$0_p = (100\%)\left[1 - \left(\frac{I_f}{R_f}\ \frac{R_n}{I_n}\right)^{\frac{1}{2}}\right] \tag{V-4}$$

This expression, which takes a reference (ambient air) measurement into account, is the one used in the Omega-1 Lidar's computer program to calculate plume opacity [Appendix B(a,b)]. The opacity value is given in percent by multiplying the expression in the brackets (Eq V-4) by 100%.

Eq (V-4) is directly applicable to data obtained and recorded through the lidar's linear channel.

If the lidar data were originally obtained and recorded using the logarithmic channel, then these data must be mathematically transformed back into linear form before they can be processed further.

The transfer function for the logarithmic amplifier was carefully and accurately measured before being incorporated into the computer program. The logarithmic amplifier output, V_{out}, is related to the input signal, V_{in}, by:

$$V_{out} = 0.04\ (\log V_{in}) + 0.18 \qquad \text{(V-5)}$$

The Biomation unit digitizes the output signal of the logarithmic channel to a digital count value (8 bit binary value, base 10) over the interval from 0 to 255. The magnitude of this range is dependent on the Biomation unit's input voltage scale selected by the lidar operator. Based on the consideration of the average operative parameters or levels of the Omega-1 Lidar's electronics, this input scale is usually 0.2 volts full scale (±0.1 V). Therefore, the digital count or binary value (C) is related to the Biomation's input voltage by (256 total counts, 0 to 255)

$$C = \frac{256}{0.2}\ \left(\frac{\text{digitizer counts}}{\text{volts}}\right) = 1280\ \text{(counts/volt)}.$$

By using the logarithmic amplifier transfer function (Eq V-5), the following is yielded:

$$C = 1280\ V_{out}$$
$$C = 1280\ [0.04\ (\log V_{in}) + 0.18]$$
$$C = 51.2\ (\log V_{in}) + 230.4 \qquad \text{(V-6)}$$

For use in the computer program [Appendix B(a,b)], the inverse logarithmic transformation is required. Therefore Eq (V-6) is solved for V_{in} as follows:

$$\log V_{in} = \frac{C-230.4}{51.2},$$

taking the antilog of both sides of this equation,

$$V_{in} = 10^{(C-230.4)/51.2}$$

and simplifying,

$$V_{in} = 10^{(1/51.2)(C-230.4)}$$

$$= 1.046^{(C-230.4)}$$

$$= 1.046^{C} \times 1.046^{-230.4}$$

$$V_{in} = 3.16 \times 10^{-5} (1.046)^{C} \qquad \text{(V-7)}$$

The constant value of 1.046 is for 0.2 volts (full scale) or ±0.1 V input scale. For other input scale values the constant value is given as follows:

Table V-4

LOGARITHMIC CHANNEL CONSTANTS

Input Voltage Scale (Volts)	Value of Constant
± 0.1	1.046
± 0.2	1.094
± 0.5	1.252

Once the inverse transformation has been applied to the logarithmic channel data, the opacity equation (Eq V-4) is used by the computer to calculate plume opacity as discussed previously in this section.

The flow of the digital lidar data under control of the computer is illustrated in Figure V-21. The analog video signals, coming from either the linear or logarithmic channels, are converted into digital form in the Biomation Fast Transient Recorder and sent to the computer. The data flows

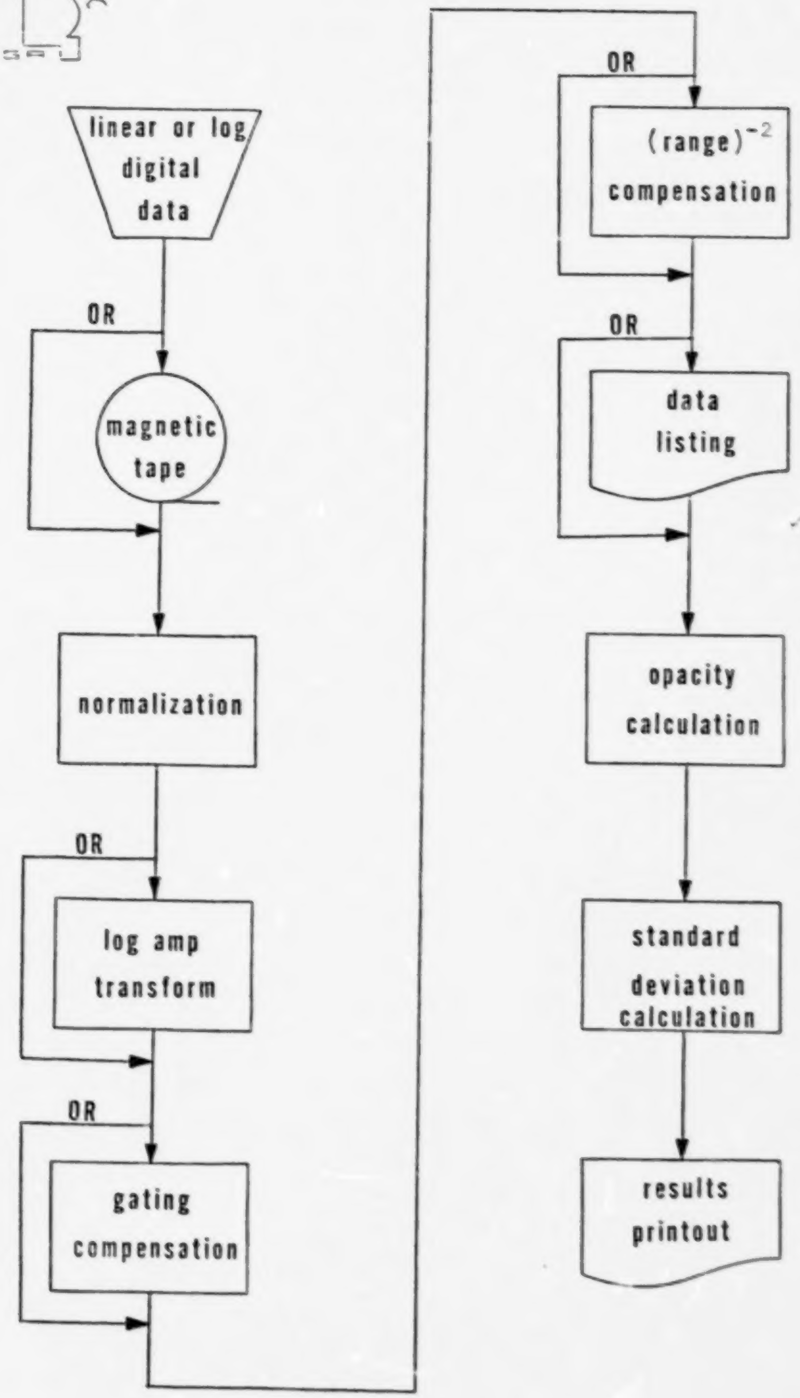

linear or log digital data
OR
magnetic tape
normalization
OR
log amp transform
OR
gating compensation
OR
(range)$^{-2}$ compensation
OR
data listing
opacity calculation
standard deviation calculation
results printout

Figure V-21 Omega-1 Lidar: Digital Data Flow Diagram

in straight-line fashion with several alternate paths as shown by the straight line and branch arrows [Figure V-21]. These paths may be selected by the lidar operator when the computer program is executed. The function of each of the blocks shown in the diagram is explained in the following paragraphs.

Regarding data acquisition, the lidar return data is read from the Biomation unit or from the magnetic tape into the computer memory. If the data are read from the Biomation, they may be optionally recorded on tape as well.

At the point of normalization, any DC bias which the data may have is removed. This is accomplished by calculating the amount of offset required to bring the zero-signal-level part of the return video signal [Figure V-11] to true zero. The offset is then subtracted from the data during subsequent calculations. The input signal offset is manually adjustable on the Biomation unit.

Scaling is performed after each subsequent computational step such that the numerical value of the data will remain in the range of 0 to 255 digital counts (arbitrary units). This is done for the convenience of data display (plotting, printing) and has no effect on the calculation of opacity.

Following the data flow sequence [Figure V-21], the logarithmic amplifier transformation is completed, if necessary, and the compensation for the video signal gating (two gates), selected by the lidar operator, is carried out if required. The $1/R^2$ correction (compensation) is carried out as required [Figures V-8 and V-9].

The digital data, stored in the computer, can be listed in tabular form for each Biomation sample interval which includes time and the corresponding digital count value. The lidar operator can select the time interval over which the data is listed. At this time in the data flow sequence, a two-dimensional plot of the linear/transformed, uncompensated/compensated data can be made.

The opacity calculation is now completed in the manner previously discussed. The most recent reference measurement is used in the calculation, Eq V-4. If no reference measurement is used, a value of 1 is assigned to the ratio R_n/R_f in the equation. Prior to executing the program on the lidar computer, the lidar operator enters the two "pick" intervals (via computer keyboard) which are the data sampling time intervals (100 nanoseconds in length) for both the near-region and the far-region of the plume under investigation. These intervals are determined by the location of the plume in the time domain (or range where the round-trip range = speed of light· time/2) and by the atmospheric conditions along the lidar's line-of-sight through the plume, as judged by the operator. (These are calculated automatically by the laboratory computer search routine discussed above.) The program calculates average values for R_n, R_f, I_n and I_f [Figure V-12] beginning at the respective pick-time point (word) and continuing for the next nine intervals for a total of 10 consecutive intervals (100 nanoseconds) resulting in a 10-point average amplitude over the interval for each R and I. The standard deviations (S_{Rn}, S_{Rf}, S_{In}, S_{If}) for the R_n, R_f, I_n and I_f average values respectively, are calculated at this point for use in the next step.

The standard deviation, S_o, of the calculated opacity, O_p, is obtained by a multi-variable function which is given in terms of the standard deviation of the individual variables. Given Eq (V-4) for opacity and the standard deviations previously calculated, the standard deviation of the opacity value is calculated using:

$$S_o = \left[\left(\frac{\partial O_p}{\partial R_n} \right)^2 S_{Rn}^{\ 2} + \left(\frac{\partial O_p}{\partial R_f} \right)^2 S_{Rf}^{\ 2} + \left(\frac{\partial O_p}{\partial I_n} \right)^2 S_{In}^{\ 2} + \left(\frac{\partial O_p}{\partial I_f} \right)^2 S_{If}^{\ 2} \right]^{\frac{1}{2}} \qquad \text{(V-8)}$$

where:

S_o = standard deviation of the opacity value, O_p.

$\partial O_p/\partial R_n$ = partial derivative of the opacity function [Equation (V-4)] with respect to the ambient-air reference signal variable in the near-region [Figure V-14].

S_{Rn} = standard deviation of the pick-interval segments for the ambient-air reference signal in the near-region.

$\partial O_p/\partial R_f$ = partial derivative of the opacity function with respect to the ambient-air reference signal variable in the far-region.

S_{Rf} = standard derivation of the pick-interval segments for the ambient-air reference signal in the far-region.

$\partial O_p/\partial I_n$ = partial derivative of the opacity function with respect to the plume backscatter signal variable in the near-region.

S_{In} = standard deviation of the pick-interval segments for the plume backscatter signal in the near-region.

$\partial O_p/\partial I_f$ = partial derivative of the opacity function with respect to the plume backscatter signal variable in the far-region.

S_{If} = standard deviation of the pick-interval segments for the plume backscatter signal in the far-region.

Equation (V-8) is a special case of a more general variance equation:[39,40]

$$
\begin{aligned}
S_o^2 = {} & \left(\frac{\partial O_p}{\partial I_n}\right)^2 S_{In}^2 + \left(\frac{\partial O_p}{\partial I_f}\right)^2 S_{If}^2 + \left(\frac{\partial O_p}{\partial R_n}\right)^2 S_{Rn}^2 + \left(\frac{\partial O_p}{\partial R_f}\right)^2 S_{Rf}^2 \\
& +2\left(\frac{\partial O_p}{\partial I_n}\,\frac{\partial O_p}{\partial I_f}\right) S_{InIf} +2\left(\frac{\partial O_p}{\partial I_n}\,\frac{\partial O_p}{\partial R_n}\right) S_{InRn} +2\left(\frac{\partial O_p}{\partial I_n}\,\frac{\partial O_p}{\partial R_f}\right) S_{InRf} \qquad \text{(V-9)} \\
& +2\left(\frac{\partial O_p}{\partial I_f}\,\frac{\partial O_p}{\partial R_n}\right) S_{IfRn} +2\left(\frac{\partial O_p}{\partial I_f}\,\frac{\partial O_p}{\partial R_f}\right) S_{IfRf} +2\left(\frac{\partial O_p}{\partial R_n}\,\frac{\partial O_p}{\partial R_f}\right) S_{RnRf}.
\end{aligned}
$$

Using Eq (V-4) for O_p, Eq (V-9) becomes:

$$\frac{\partial O_p}{\partial I_n} = \frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{-\frac{1}{2}}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n{}^2}\right) \equiv \frac{1}{2I_n}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{\frac{1}{2}}$$

$$\frac{\partial O_p}{\partial I_f} = -\frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{-\frac{1}{2}}\frac{R_n}{R_fI_n} = -\frac{1}{2I_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{\frac{1}{2}}$$

$$\frac{\partial O_p}{\partial R_n} = -\frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{-\frac{1}{2}}\frac{I_f}{R_fI_n} = -\frac{1}{2R_n}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{\frac{1}{2}}$$

$$\frac{\partial O_p}{\partial R_f} = \frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{-\frac{1}{2}}\left(\frac{I_f}{R_f{}^2}\,\frac{R_n}{I_n}\right) = \frac{1}{2R_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{\frac{1}{2}} .$$

Substituting these partial derivatives into $S_o{}^2$:

$$S_o{}^2 = \frac{1}{4I_n{}^2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{In}{}^2 + \frac{1}{4I_f{}^2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{If}{}^2 + \frac{1}{4R_n{}^2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{Rn}{}^2$$

$$+ \frac{1}{4R_f{}^2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{Rf}{}^2 - \frac{1}{2I_nI_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{InIf} - \frac{1}{2I_nR_n}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{InRn}$$

$$+ \frac{1}{2I_nR_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{InRf} + \frac{1}{2I_fR_n}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{IfRn} - \frac{1}{2I_fR_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{IfRf}$$

$$- \frac{1}{2R_nR_f}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)S_{RnRf}.$$

$$S_o{}^2 = \frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)\left[\frac{S_{In}{}^2}{2I_n{}^2} + \frac{S_{If}{}^2}{2I_f{}^2} + \frac{S_{Rn}{}^2}{2R_n{}^2} + \frac{S_{Rf}{}^2}{2R_f{}^2} - \frac{S_{InIf}}{I_nI_f} - \frac{S_{InRn}}{I_nR_n}\right.$$

$$\left. + \frac{S_{InRf}}{I_nR_f} + \frac{S_{IfRn}}{I_fR_n} - \frac{S_{IfRf}}{I_fR_f} - \frac{S_{RnRf}}{R_nR_f}\right]. \qquad \text{(V-10)}$$

The terms within Eq (V-10) are defined in Equations (V-11) through (V-13). The variance terms are the following:

$$S_{In}^{2} = \sum_{i=1}^{m} \frac{(I_{ni} - I_{n})^{2}}{(m-1)} , \quad S_{If}^{2} = \sum_{i=1}^{m} \frac{(I_{fi} - I_{f})^{2}}{(m-1)}$$

$$S_{Rn}^{2} = \sum_{i=1}^{m} \frac{(R_{ni} - R_{n})^{2}}{(m-1)} , \quad S_{Rf}^{2} = \sum_{i=1}^{m} \frac{(R_{fi} - I_{f})^{2}}{(m-1)} . \tag{V-11}$$

The functional or variable terms are:

$$I_{n} = \frac{1}{m} \sum_{i=1}^{m} I_{ni} , \quad I_{f} = \frac{1}{m} \sum_{i=1}^{m} I_{fi} ,$$

$$R_{n} = \frac{1}{m} \sum_{i=1}^{m} R_{ni} , \quad R_{f} = \frac{1}{m} \sum_{i=1}^{m} R_{fi} . \tag{V-12}$$

The covariance terms between the variables I_n, I_f, R_n, and R_f are:

$$S_{InIf} = \sum_{i=1}^{m} \frac{(I_{ni}-I_{n})(I_{fi}-I_{f})}{(m-1)} , \quad S_{InRn} = \sum_{i=1}^{m} \frac{(I_{ni}-I_{n})(R_{ni}-R_{n})}{(m-1)} ,$$

$$S_{InRf} = \sum_{i=1}^{m} \frac{(I_{ni}-I_{n})(R_{fi}-R_{f})}{(m-1)} , \quad S_{IfRn} = \sum_{i=1}^{m} \frac{(I_{fi}-I_{f})(R_{ni}-R_{n})}{(m-1)} , \tag{V-13}$$

$$S_{IfRf} = \sum_{i=1}^{m} \frac{(I_{fi}-I_{f})(R_{fi}-R_{f})}{(m-1)} , \quad S_{RnRf} = \sum_{i=1}^{m} \frac{(R_{ni}-R_{n})(R_{fi}-R_{f})}{(m-1)} .$$

In the development of Eq (V-8), it was assumed that for the lidar application the covariance terms would sum to zero, thus leaving only the variance terms, i.e.,

$$S_o^2 = \frac{1}{4}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)\left[\frac{S_{In}^2}{I_n^2} + \frac{S_{If}^2}{I_f^2} + \frac{S_{Rn}^2}{R_n^2} + \frac{S_{Rf}^2}{R_f^2}\right] \qquad \text{(V-14)}$$

$$S_o = \frac{1}{2}\left(\frac{I_f}{R_f}\,\frac{R_n}{I_n}\right)^{\frac{1}{2}}\left[\frac{S_{In}^2}{I_n^2} + \frac{S_{If}^2}{I_f^2} + \frac{S_{Rn}^2}{R_n^2} + \frac{S_{Rf}^2}{R_f^2}\right]^{\frac{1}{2}} \qquad \text{(V-15)}$$

The standard deviation S_o of the opacity value O_p is obtained by Eq (V-15) which has been derived from Eq (V-8). The assumption of zero-covariance was verified over the opacity range from 0 to 75%. The verification is reported in Section VI of this document. The standard deviation is given in percent by multiplying the S_o value by 100%.

The largest and most significant source of error in O_p is the atmospheric inhomogeneities along the lidar's line-of-sight resulting in video signal noise. The standard deviation S_o is an indication of the magnitude of the atmospheric signal noise in the near-region and far-region pick intervals used in the calculation of O_p.

The computer printout of the data analyst's report [Figure V-22], containing all pertinent information from the data analysis, consists of the following parameters:

- Tape header (information block) recorded in the field,
- Month, date, year that the lidar signal was recorded,
- Individual file number of lidar signal on the magnetic tapes,
- Individual file number of the reference signal used in each respective opacity calculation,
- Time values of the near-and far pick intervals in nanoseconds T_n, T_f,
- Average values of I_n (X_n), I_f (X_f), R_n, R_f,
- Standard deviation values for I_n, I_f, R_n, R_f,
- Opacity value, O_p,
- Standard deviation, S_o,
- Running average values, $\bar{O}_p$, $\bar{S}_o$.

```
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, NATIONAL ENFORCEMENT INVESTIGATIONS CENTER,  DENVER, COLORADO 80225
Omega-0028, Co. Name.,  City,      State, Source Name
                                                              LINEAR CHANNEL,        10 NS/PT, +OR- 0.10 VOLTS
GATE 1  0.0 DB      0 TO      0 NS,  GATE 2  0.0 DB      0 TO      0 NS,  CALIBRATION FILE    0,  AZ=  0.0,   EL= 0.0

OMEGA-1 LIDAR OPACITY DATA.        ANALYZED      BY ANALYST'S NAME

12/ 4/79  22:30: 4  FILE  105  REF FILE    1
TN=11470  XN= 180. 3 +OR-  9. 5 RN= 156. 5 +OR-  5. 5  TF=12850  XF= 121. 4 +OR-  3. 1 RF= 156. 9 +OR-  8. 0
OP= 18. 0% +OR-  3. 5           FOR  4. 93 MINUTES  66 OP'S AVE  19. 4%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30: 8  FILE  106  REF FILE    1
TN=11470  XN= 165. 1 +OR-  7. 0 RN= 156. 5 +OR-  5. 5  TF=12680  XF= 115. 5 +OR-  3. 4 RF= 150. 0 +OR- 10. 0
OP= 14. 6% +OR-  3. 9           FOR  5. 00 MINUTES  67 OP'S AVE  19. 4%              67 STD DEV'S AVE  4. 4

12/ 4/79  22:30:13  FILE  107  REF FILE    1
TN=11500  XN= 156. 9 +OR-  3. 5 RN= 165. 3 +OR-  7. 2  TF=12880  XF=  94. 2 +OR-  8. 9 RF= 171. 0 +OR-  9. 8
OP= 23. 8% +OR-  4. 6           FOR  4. 95 MINUTES  66 OP'S AVE  19. 4%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:17  FILE  108  REF FILE    1
TN=11500  XN= 160. 4 +OR-  7. 7 RN= 165. 3 +OR-  7. 2  TF=12810  XF=  97. 2 +OR-  2. 4 RF= 169. 0 +OR- 11. 2
OP= 23. 0% +OR-  3. 7           FOR  4. 95 MINUTES  66 OP'S AVE  19. 4%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:22  FILE  109  REF FILE    1
TN=11500  XN= 161. 8 +OR-  8. 0 RN= 165. 3 +OR-  7. 2  TF=12900  XF= 103. 9 +OR-  5. 4 RF= 173. 7 +OR- 13. 5
OP= 21. 8% +OR-  4. 5           FOR  4. 95 MINUTES  66 OP'S AVE  19. 4%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:27  FILE  110  REF FILE    1
TN=11500  XN= 169. 4 +OR- 10. 3 RN= 165. 3 +OR-  7. 2  TF=12900  XF= 108. 8 +OR-  5. 9 RF= 173. 7 +OR- 13. 5
OP= 21. 8% +OR-  4. 7           FOR  4. 95 MINUTES  66 OP'S AVE  19. 5%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:31  FILE  111  REF FILE    1
TN=11500  XN= 173. 4 +OR- 14. 0 RN= 165. 3 +OR-  7. 2  TF=12850  XF=  97. 4 +OR-  3. 9 RF= 167. 2 +OR-  8. 5
OP= 25. 5% +OR-  4. 2           FOR  4. 95 MINUTES  66 OP'S AVE  19. 5%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:36  FILE  112  REF FILE    1
TN=11500  XN= 159. 9 +OR-  6. 7 RN= 165. 3 +OR-  7. 2  TF=12850  XF=  72. 4 +OR-  7. 5 RF= 167. 2 +OR-  8. 5
OP= 33. 1% +OR-  4. 4           FOR  4. 95 MINUTES  66 OP'S AVE  19. 7%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:40  FILE  113  REF FILE    1
TN=11500  XN= 154. 6 +OR- 15. 0 RN= 165. 3 +OR-  7. 2  TF=12860  XF=  59. 2 +OR-  4. 2 RF= 166. 8 +OR-  8. 7
OP= 38. 4% +OR-  4. 3           FOR  4. 93 MINUTES  66 OP'S AVE  20. 0%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:45  FILE  114  REF FILE    1
TN=11500  XN= 156. 5 +OR-  6. 1 RN= 165. 3 +OR-  7. 2  TF=12860  XF=  53. 0 +OR-  2. 9 RF= 166. 8 +OR-  8. 7
OP= 42. 0% +OR-  2. 8           FOR  4. 95 MINUTES  66 OP'S AVE  20. 4%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:50  FILE  115  REF FILE    1
TN=11500  XN= 165. 6 +OR-  9. 6 RN= 165. 3 +OR-  7. 2  TF=12860  XF=  48. 9 +OR-  4. 4 RF= 166. 8 +OR-  8. 7
OP= 45. 9% +OR-  3. 4           FOR  4. 95 MINUTES  66 OP'S AVE  20. 8%              66 STD DEV'S AVE  4. 4

12/ 4/79  22:30:54  FILE  116  REF FILE    1
TN=11500  XN= 175. 5 +OR-  7. 3 RN= 165. 3 +OR-  7. 2  TF=12860  XF=  49. 7 +OR-  4. 4 RF= 166. 8 +OR-  8. 7
OP= 47. 0% +OR-  3. 2           FOR  4. 95 MINUTES  66 OP'S AVE  21. 2%              66 STD DEV'S AVE  4. 4
```

Figure V-22 Omega-1 Lidar Opacity Data Analyst's Report Format

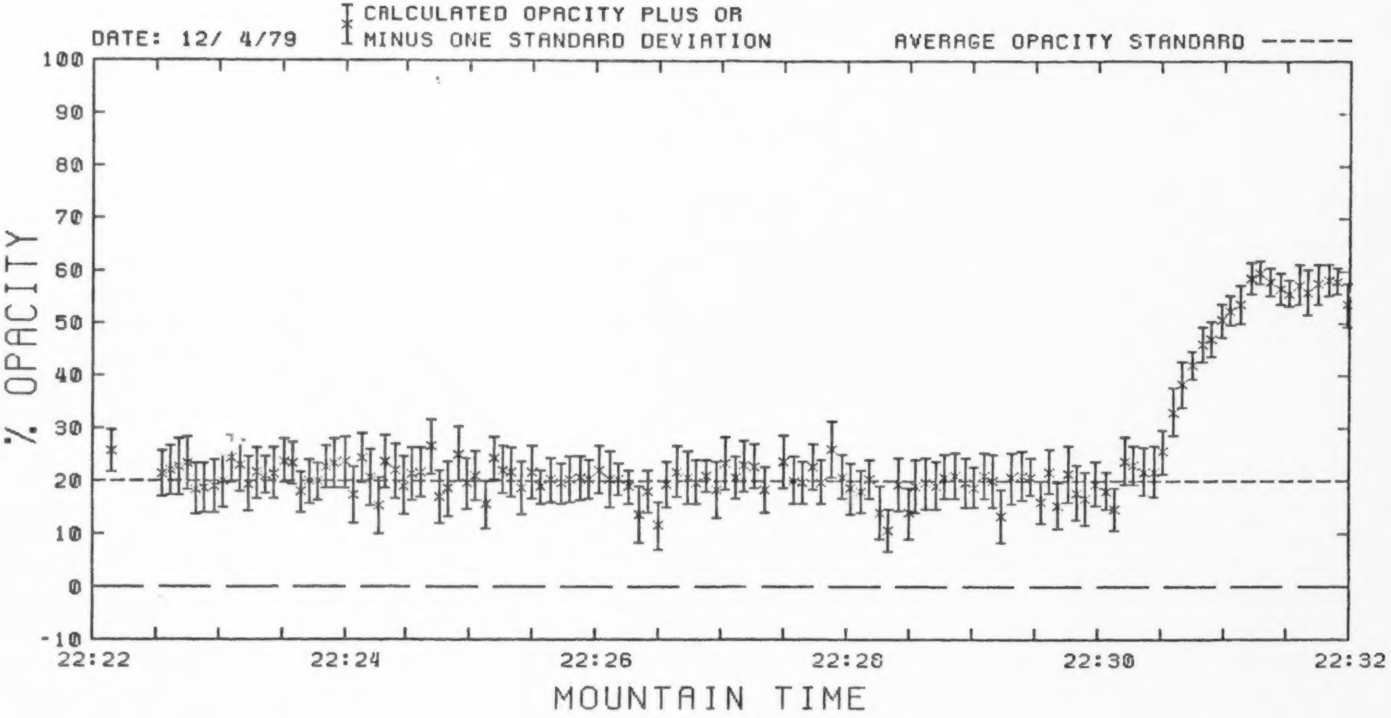
During the execution of the opacity calculation, the computer is programed to inspect the variability of the near-region and far-region signal segments and the value of S_o. If the standard deviation of S_o is greater than 8% the lidar computer prints an error indication immediately after the opacity value is printed. This form of an acceptance/rejection criterion [see Section VIII for detailed discussion] is carried out for each lidar signal analyzed. If a negative opacity value is calculated, which means that the backscatter amplitude in the far-region (behind the plume) is greater than that in the near-region, usually due to fumigation from a neighboring source, the lidar computer also prints an error indication.

The lidar data, recorded on magnetic tape, is also processed at NEIC on the PDP-11-70 computer which is much faster than the lidar's computer. The same program elements are used on the larger computer [see Section VIII for more detail].

The temporal plume opacity values for a given source and associated standard deviations, are plotted in a two-dimensional format along with the applicable average opacity value established by a particular regulation. Examples of such plots are given in Figures V-23 and V-24, where the latter plot is a continuation of the first plot. Each plot is 10 minutes in length along the abscissa or horizontal axis. The vertical bars represent ±1 standard deviation calculated for each respective opacity value. If a particular regulation being enforced has an individual opacity maximum value, then that value will also be plotted by a dashed line.

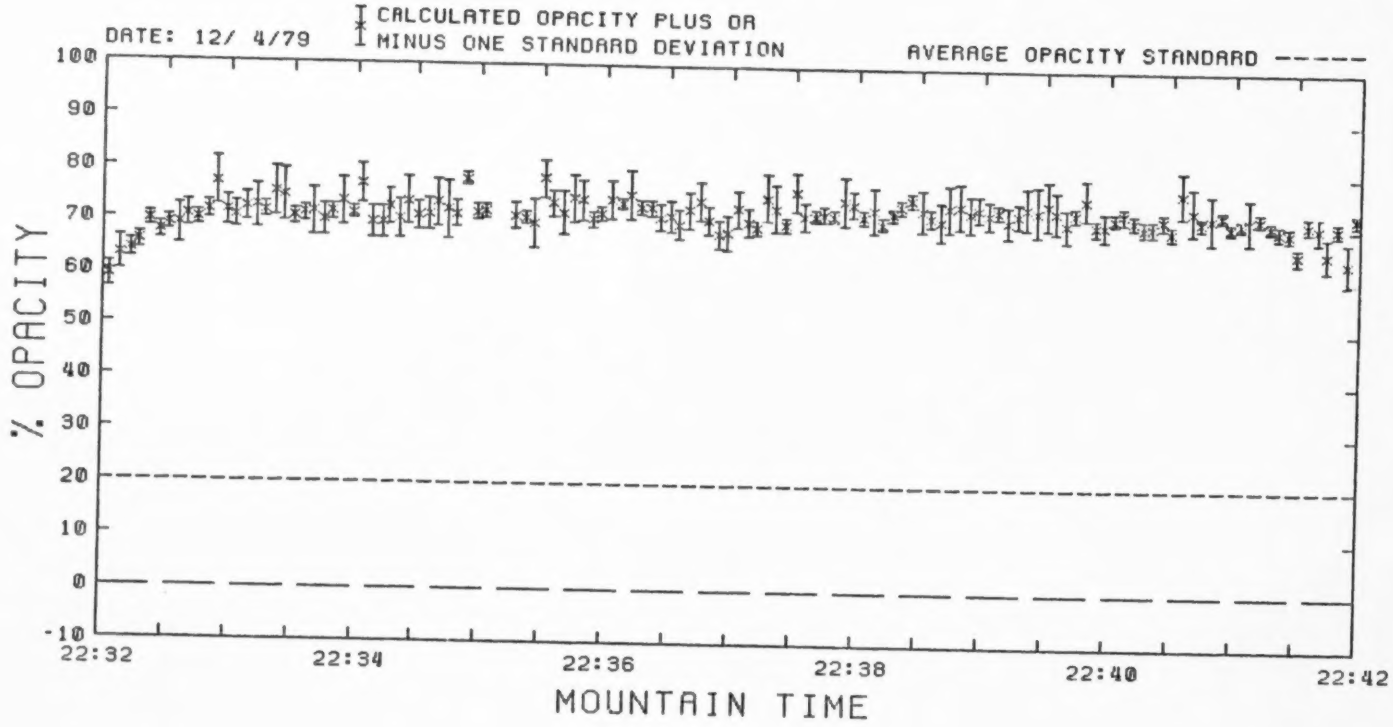
The computer also calculates and plots running averages of the opacity value data. The length of the time period of the running average is defined by a particular state air regulation or New Source Performance Standard (NSPS). A running average is defined in the following way:

If i opacity values, from M to N, have been averaged over a given time interval, the running average is performed by successively subtracting the Mth value and adding the N+1 value and calculating the average for the i



XXXX STACK, FACILITY NAME, CITY, STATE

Figure V-23 Two-Dimensional Plot of Omega-1 Lidar Opacity Data



XXXX STACK, FACILITY NAME, CITY, STATE

Figure V-24 Two-Dimensional Plot of Omega-1 Lidar Opacity Data-Continued

opacity values again, then subtracting M+1 and adding N+2 and performing the calculation again, etc. [see Section VIII]. The number of values averaged in this manner is always i.

The advantage of this technique is to continually have available the average opacity of a given source over a running 5 or 6 minute period appearing in state air regulations and the NSPS. The running average does not apply to aggregate-type regulations.

The Omega-1 Lidar can fire the laser, collect the return signal and record the resultant A-scope video signal on magnetic tape at a rate of about once every second. If an opacity value is calculated for each lidar signal, then the data rate is decreased to about one measurement every 2 seconds. The data rate is continuously variable from one signal-per-second to a single signal.

The lidar is mounted in an enclosed metal-lined van which is, in turn, mounted on a 1977 Ford C600 truck [Figures V-25 and V-26]. The van has three separate rooms: a) laser room, b) computer room, and c) generator room.

The laser and computer rooms are equipped with heaters and air conditioners providing environmental control for year-round operation.

There are two electrical generators mounted in the generator room which is across the front of the van [Figure V-27]. The upper-level generator supplies regulated 110-120 VAC power to the system's electronics. The internal lights are also powered from this unit. The large generator (30 KVA) supplies electrical power to the laser (18 KVA) power supplies, the water refrigeration unit, and the air conditioning units.

The doors in the rear of the van open so as to provide a clear or unobstructed pointing position anywhere in the solid angle of ±90° in azimuth (180° total azimuth) and of -10° to +90° in elevation. From the time the truck is stopped at a given monitoring site, the lidar is in full operation

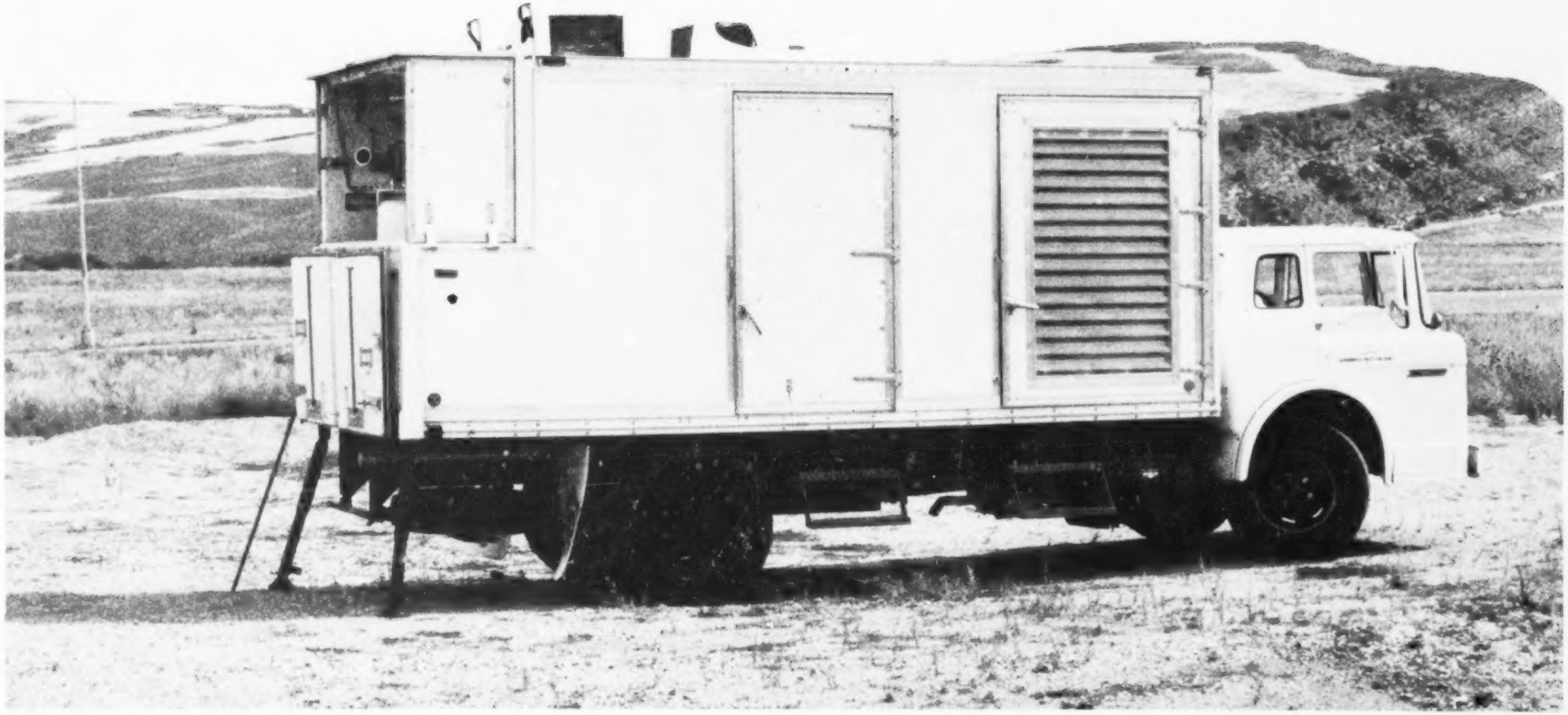


Figure V-25 Omega-1 Mobile Lidar System: View Of Right Side

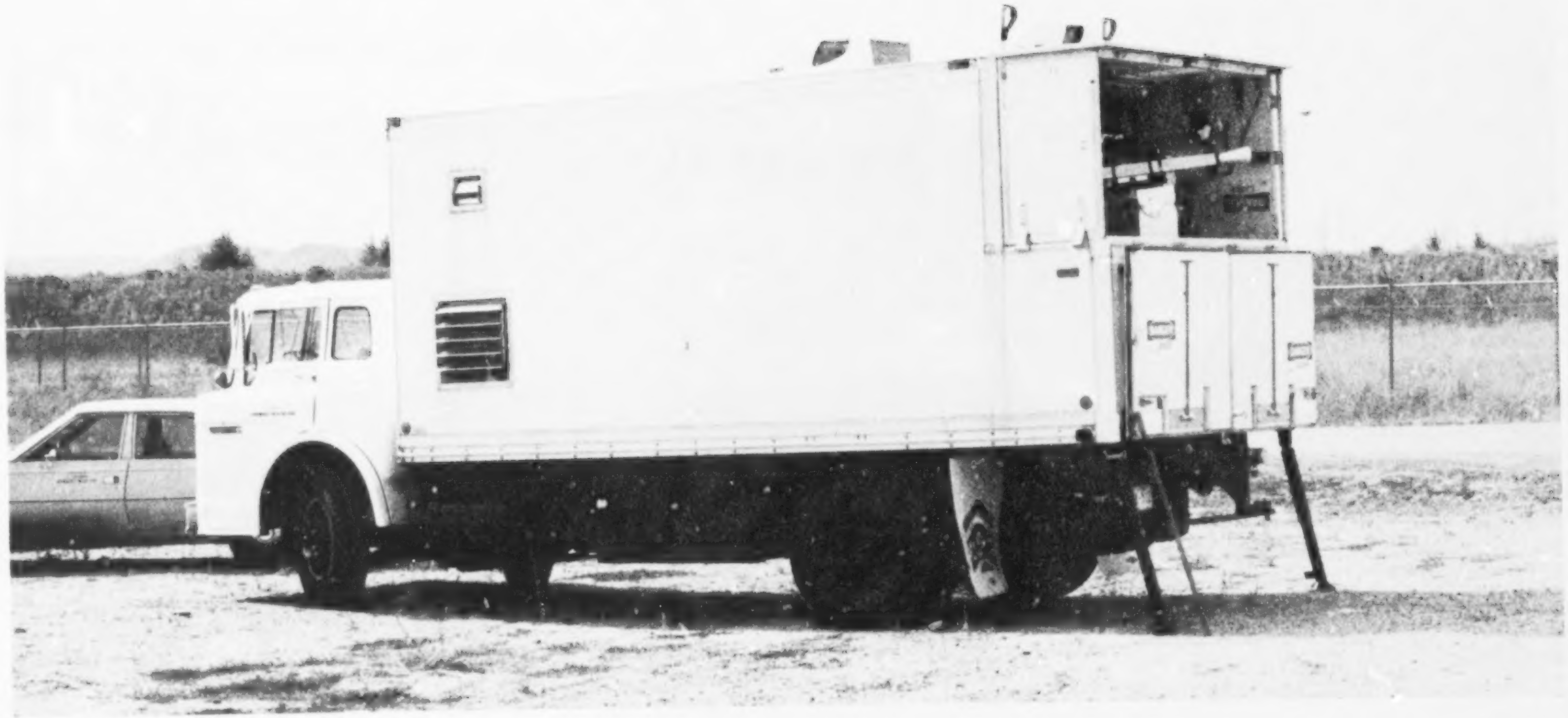


Figure V-26 Omega-1 Mobile Lidar System: View Of Left Side

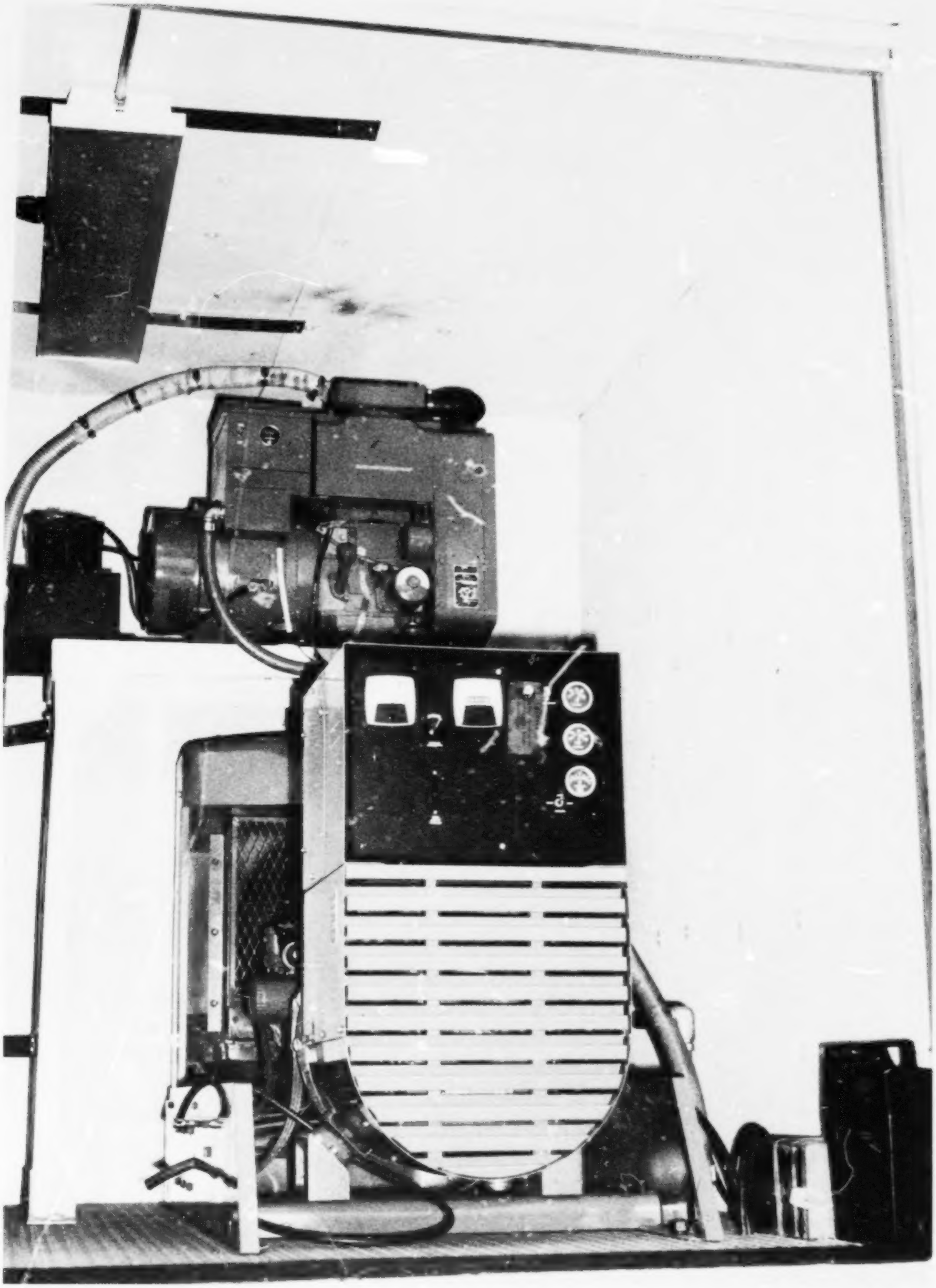


Figure V-27 Omega-1 Lidar: Generator Room

in less than 10 minutes, day or night. The lidar is quickly and easily aimed at a smoke plume in question by either direct viewing through the Celestron telescope or through an aiming (rifle) scope mounted on the lidar pedestal and bore-sighted to the Celestron telescope.

There is also a small door in the top of the van, at the back as shown in Figure V-28, that provides a vertical line-of-sight for the lidar. The lidar can be operated through this door with the vehicle standing or in motion. This arrangement permits the spatial or temporal monitoring of:

a) plume drift and dispersion characteristics/dynamics,
b) plume behavior such as fumigation, coning, etc.,
c) location and movement of the combining of plumes,
d) plume density variations,
e) vertical burden and inversion layers

to name a few. These modes, in addition to the remote measurement of plume opacity, can be conducted during either day- or nighttime hours. (The lidar receiver is solar-blind; however, it cannot be aimed directly into the sun.) The data collected during these modes of operation are analyzed on the NEIC laboratory computer and the results plotted on a two-dimensional plotter in a variety of formats.

Lidar is not effective for plume opacity monitoring during heavy rain storms, snow storms, and fog conditions.

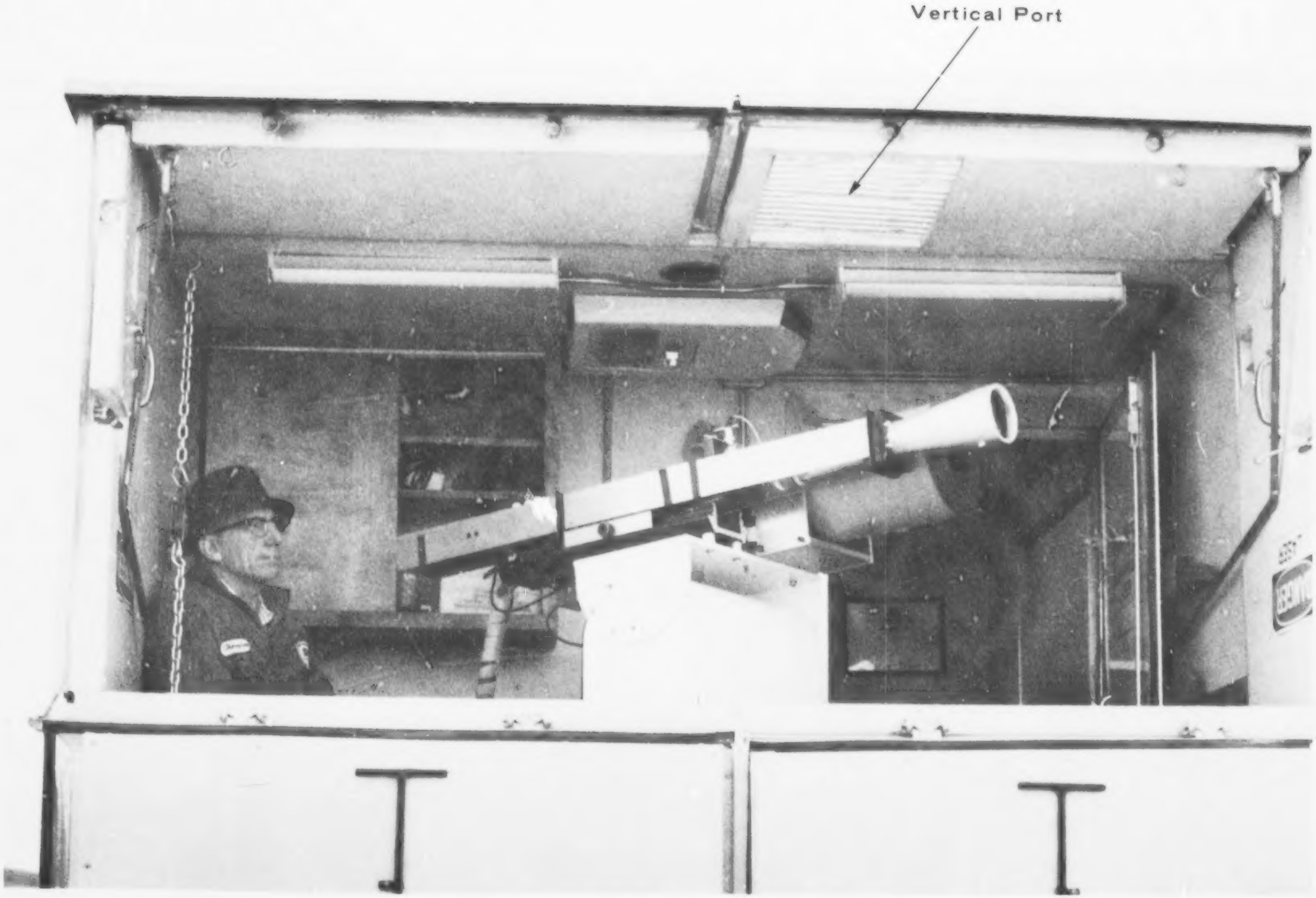

Vertical Port

Figure V-28 Omega-1 Lidar: Rear View

VI. PERFORMANCE EVALUATION AND THE CALIBRATION MECHANISM OF THE OMEGA-1 LIDAR

During the time that the contractor was fabricating the Omega-1 Lidar and even after it was accepted, EPA technical personnel, with the advice and counsel of lidar specialists from two separate EPA contractors, formulated a detailed performance evaluation program and formulated the design necessary for an effective calibration mechanism.

The performance evaluation tests were not designed for proof-of-principle of the lidar technique since that had been done several years prior.[5,22] These historical tests, performed with two different lidars (EPA-RTP Lidar* and the SRI International Mark IX Lidar**) having ruby lasers as optical transmitters, have clearly established the validity of the lidar mechanism and produced technical/logistic information that was used extensively in the design of the Omega-1 Lidar which is an optimum system for field use in the measurement of plume opacity. The performance evaluation tests were designed to fully evaluate the performance parameters and characteristics of the Omega-1 Lidar revealing any anomalies that might have been present. The results of these tests given later in this section, apply only to a lidar equipped with a ruby laser.

EPA technical personnel judged the following tests as those necessary and sufficient to demonstrate that the Omega-1 Lidar measures the opacity of visible particulate emissions with consistently high accuracy:

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* *This lidar belongs to the Environmental Sciences Research Laboratory, EPA, Research Triangle Park, North Carolina 27111.*

** *This lidar belongs to the Atmospheric Science Center, SRI International, Menlo Park, California, 94025*

a) Aerosol Chamber Tests - A technical investigation revealed that the SRI/EPA aerosol chamber, previously established and operated as a simulator for particulate plumes, provided a realistic outdoor laboratory environment for establishing and evaluating the performance/response characteristics of lidar systems for smoke plume opacity measurements. The aerosols used to generate the smoke plumes were flyash (black) and iron oxide (rust red) particulates which were characterized by particle-size distribution classes or ranges.

The lidar performance tests conducted, using the aerosol chamber as the simulated smoke plume, were preliminary tests or first-run tests for the purpose of establishing the base-line performance of the Omega-1 Lidar and uncovering the anomalies that were found in the system.

b) Internal Calibration Mechanism - In order to establish the validity of the visible emissions opacity data obtained with the Omega-1 Lidar, a rather simple mechanism was formulated and designed for testing the lidar system performance in the field under conditions, as nearly as possible, identical to those encountered during actual plume measurements. This test is a demonstration of the accuracy of the lidar opacity measurement which depends on the verification of the proper operation, linearity* and repeatability in performance of all the electronics in the lidar receiver from the photomultiplier tube (PMT) detector through the computer. This test, which requires from 1 to 3 minutes to perform, serves as a performance verification mechanism for the proof-of-proper-operation requirements of the evidentiary chain employed in the EPA enforcement activities. This test is performed for discrete opacity values ranging from 0% through approximately 80%.

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* *Linearity is defined by the equation $y = mx + b$. For a given change in x there is a corresponding proportional change in y. The proportionability factor m is not a function of x or y but is a constant. x is the input signal amplitude, y is the output signal amplitude, m is the slope of straight line and b is the intercept point where the line crosses the y axis of a two dimensional graph.*

c) PMT Evaluation Tests - The PMT detector is the key component in the lidar receiver. The EPA-RTP lidar encountered a problem with afterpulsing with that system's PMT. (Afterpulsing, also called signal-induced noise, is defined as the departure of the output electronic signal of the PMT from the predicted or expected values immediately after an encounter with a strong optical signal. The strong optical signal is the backscatter signal from the smoke plume under-test and the afterpulsing occurs in far region segment of the video signal just beyond the plume.)

The Omega-1 Lidar's PMT (ITT 4084) is of special design. The design of this detector was based on the results obtained through research with the EPA-RTP Lidar, and has eliminated the after--pulsing problem.

During the time just prior to the aerosol chamber tests SRI International conducted numerous tests on the Omega-1 Lidar's PMT. These tests showed that there were no after-pulsing effects in this PMT. The PMT performance tests are repeated periodically, at least every 6 months, to verify that the tube performance characteristics have not changed. Additional tests performed on this PMT are given later in this section.

d) Field Experimentation Tests - The field tests have been used extensively for studying the intrinsic operating characteristics and the correlation among lidar-measured opacity values, visible emissions observation opacity values, and the respective in-stack transmissometer opacity values. The tests have also been used to train lidar operators and to optimize the operation and performance of the lidar system and the computer software used in internal data management and recording. The data recorded during these tests have been analyzed and documented in a systematic data base for future reference/use.

More detailed information and test results are given in the remainder of this section.

AEROSOL CHAMBER TESTS

These outdoor laboratory tests were conducted at the facilities of SRI International (formerly Standard Research Institute) in Menlo Park, California. (Refer to Section III for background information.)

The test site consisted of a vacant lot, an aerosol chamber[11,41] 9.75 meters (32 ft) in length and a back-stop for the laser beam, as shown in Figure VI-1. The overall length of the optical path (lidar to back-stop) through the aerosol chamber was 281 meters (922 ft). The aerosol chamber is a device used to simulate actual particulate plumes with a high degree of laboratory control over the applicable parameters, especially plume opacity. The simulation of a plume is accomplished by feeding submicron-to-10 micron size particulates (size selectable) into the aerosol chamber by a particle feeder and a high volume (5800 ft^3/m(cfm)) blower [Figure VI-2]. The particulates are metered into the air stream by the groove and disk feeder [Figure VI-1]. The particulate-laden air stream is highly controlled from the feeder through the aerosol chamber into the sighting tunnel which has an effective path length of 9.1 meters (30 ft). It is decelerated in an expanding duct network before entering the sighting tunnel. The particulates do not escape from the sighting tunnel through the sighting ports because an aerosol curtain is used to establish and maintain a fixed boundary to the particulate-laden air through which the lidar can sight without affecting the transmission of the laser energy. The particulate-laden air escapes the chamber through the exhaust ports on top [Figure VI-1] away from the lidar's line-of-sight through the sighting tunnel. The effective plume opacity is controlled directly by the density of the particulate-laden air within the sighting tunnel.

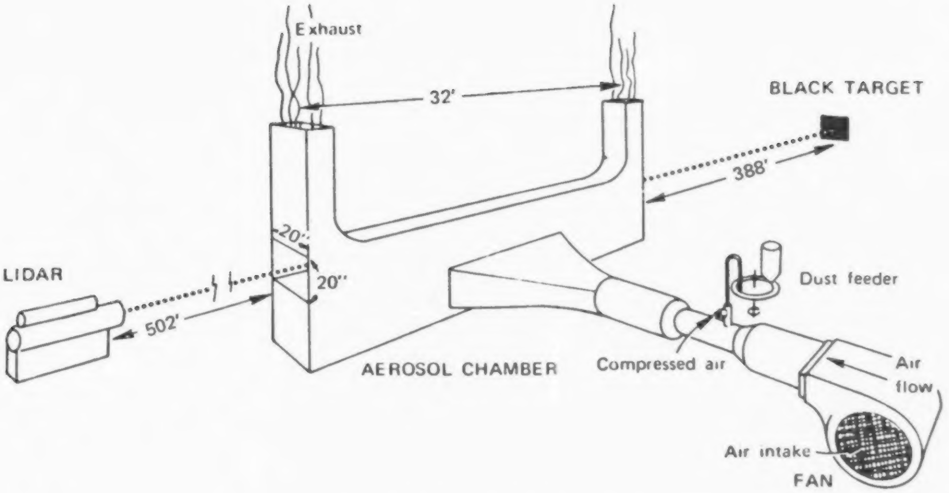
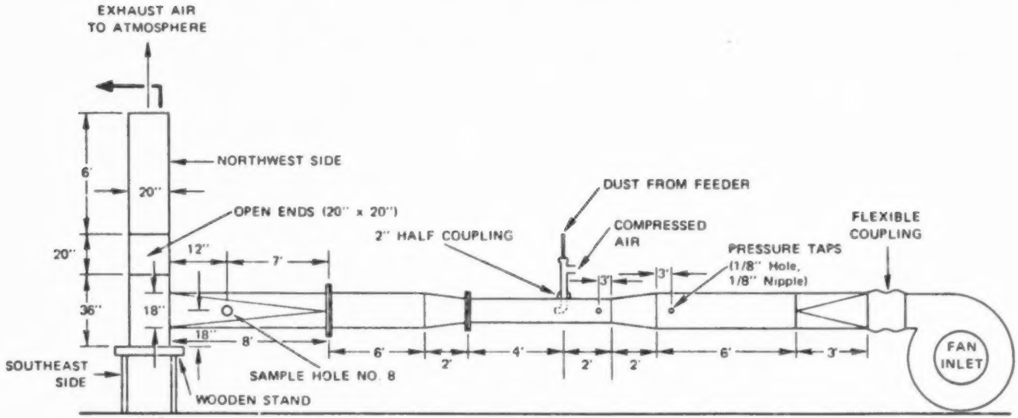
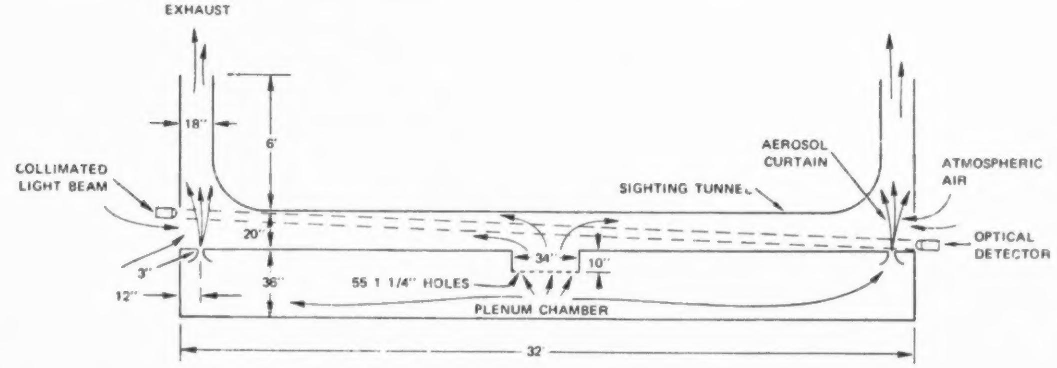

Exhaust
32'
BLACK TARGET
388'
20"
20"
LIDAR
502'
Dust feeder
Compressed air
AEROSOL CHAMBER
Air
flow
Air intake
FAN

Figure VI-1 DIAGRAM OF EXPERIMENTAL SYSTEM [41]


EXHAUST AIR TO ATMOSPHERE
NORTHWEST SIDE
6'
20"
OPEN ENDS (20" x 20")
20"
12"
7'
2" HALF COUPLING
DUST FROM FEEDER
COMPRESSED AIR
3'
3'
PRESSURE TAPS (1/8" Hole, 1/8" Nipple)
FLEXIBLE COUPLING
36"
18"
18"
8'
6'
2'
4'
2'
2'
6'
3'
FAN INLET
SOUTHEAST SIDE
SAMPLE HOLE NO. 8
WOODEN STAND

(a) ELEVATION


EXHAUST
18"
6'
COLLIMATED LIGHT BEAM
AEROSOL CURTAIN
SIGHTING TUNNEL
ATMOSPHERIC AIR
20"
34"
10"
OPTICAL DETECTOR
3"
36"
55 1 1/4" HOLES
12"
PLENUM CHAMBER
32'

(b) SECTIONAL VIEW OF AEROSOL SIGHTING CHAMBER (Section B-B)

Figure VI-2 AEROSOL CHAMBER DETAILS[41]

Since plume opacity is defined as one minus plume optical transmittance, an optical transmissometer was incorporated into the aerosol chamber's sighting tunnel in order to continually monitor the optical transmittance of the particulate-laden air over the 9.1 meter effective path length through the sighting tunnel. The transmissometer was a photoptic response white-light transmissometer directed along the sighting tunnel as shown in Figure VI-2. The source, a tungsten filament lamp, was located at one end of the sighting tunnel while the optical detector, a silicon detector, was located at the other end. The transmissometer's receiver was equipped with a special optical filter to approximate the response of the human eye, since visible emissions observations are collected by human observers (Reference Method 9). This transmissometer had an integration time constant of about 0.25 sec., indicating that it could monitor any moderate opacity changes rapidly and effectively. The transmissometers in the 40 CFR Part 60 smoke generators have a white-light source and a time constant of 5 seconds or less [Table 9-1, Reference Method 9 (see Field Experiment section)].

Calibration tests performed on this transmissometer showed it to respond in a linear manner (to within 1% transmittance) to neutral density (shades of gray) optical filters placed in its beam path. Its calibration was checked just prior to the start of each lidar-chamber data run. The opacity values of the particulate-laden air were recorded on a continuous strip-chart recorder and on a digital printer which was activated by a signal from the lidar when the laser was fired through the sighting tunnel.

The particulates used during these tests were four size fractions of flyash (black particulates) and one of iron oxide (rust red particulates). The four size fractions (particulate diameters) of flyash were: 1) 0.1 to 10 microns, 2) 0.1 to 2.5 microns, 3) 2.5 to 5 microns and 4) 5 to 10 microns. The lidar and the chamber transmissometer measured the plume opacity for all the above-mentioned size fractions.

The performance evaluation tests were performed during a 4-week period. Prior to recording actual lidar data through the aerosol chamber, tests were conducted in order to establish the proper operating signal levels of the Omega-1 Lidar's photomultiplier (PMT) detector, linear and logarithmic channels and the Biomation 8100 Fast Transient Recorder (digitizer).* The new internal calibration mechanism (discussed later in this section of the report) was installed and was used extensively in these tests. Once these tests were satisfactorily completed, the lidar was then aimed and fired down the test range through the sighting tunnel of the aerosol chamber [Figure VI-1]. A photograph of the aerosol chamber is shown in Figure VI-3.

Two problems were encountered within the lidar. One problem involved the electronic signal interference in the lidar receiver caused by the Pockel Cell Q-Switch in the laser. This interference is called electromagnetic interference (EMI). This problem was solved by rerouting the electronic signal (video) cable, from the PMT detector to the processing electronics, away from the Q-Switch power supply and remote control cables. Also an additional electronic shield was put on the electronic signal cable and grounded or terminated at both ends. The high voltage cables from the Q-Switch power supply to the Q-Switch, located within the laser invar rails, were twisted and additional shielding installed with proper termination. Diagnostic tests were then performed revealing that the EMI noise problems were greatly reduced to an acceptable level.

As viewed on the oscilloscope display this EMI noise was barely visible in the receiver's inherent electronic noise level that is always present in the time interval from the time the receiver is effectively turned on to the time the laser is fired; it had no effect upon the higher amplitude signals used in the opacity calculation.

The second problem mentioned above involved the beam pattern out of the Holobeam (Model 624) laser's upcollimating telescope, which is a beam-shaping device. It had a noticeable amount of energy in the first secondary maximum surrounding the intense central spot or primary maximum. This

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* *At this time the Biomation digitizer was taken to the Biomation factory for complete calibration.*

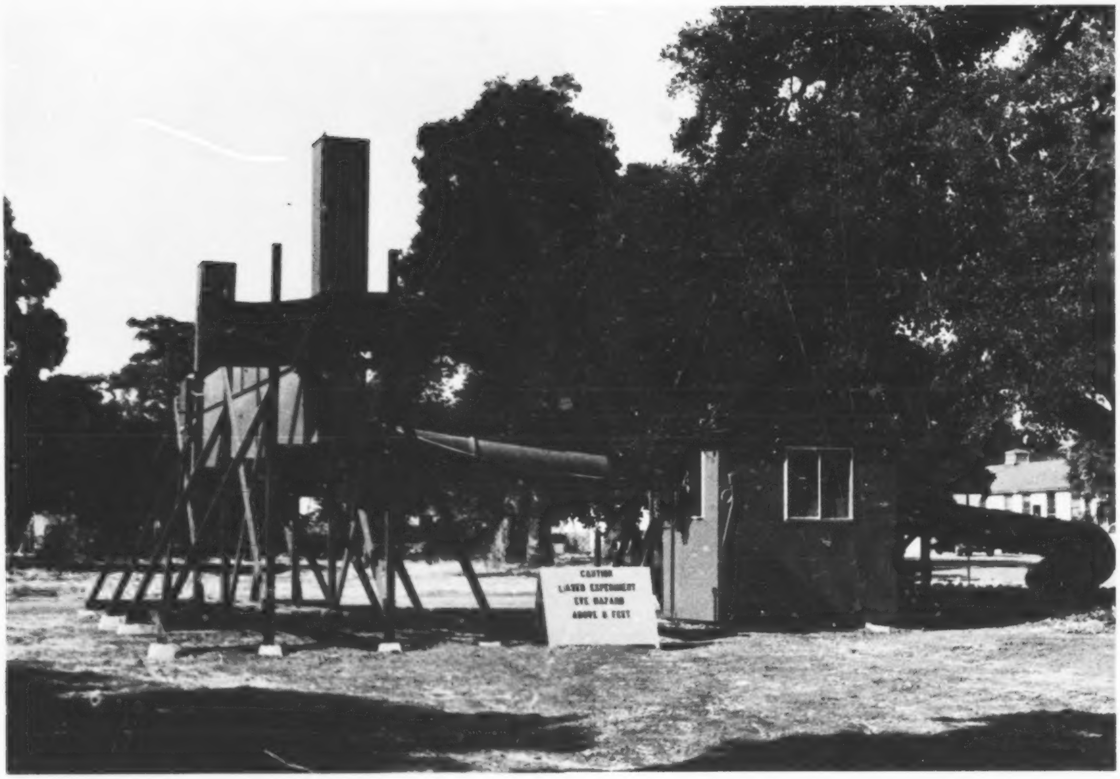

CAUTION
LASER EXPERIMENT
EYE HAZARD
ABOVE 6 FEET

Figure VI-3 SRI International Aerosol Test Chamber Facility
(As Viewed From The Lidar End)

effect was evident in the large laser energy reflection signal from the front surface of the aerosol chamber as recorded and observed on the oscilloscope display. The entire optical train (all optical elements along the laser's invar rails) was realigned including the upcollimator. This problem had no effect upon the opacity measurements of the particulate plume within the aerosol chamber [see Section V for signal processing details]; however, it did produce a larger return signal than normal from the chamber structure. It was decided at that time that the upcollimator would have to be changed, reworked as required and refocused for proper performance (beam shape) in the NEIC Optics Laboratory in Denver.

The Omega-1 Lidar tests using the aerosol chamber were divided into runs. Each run consisted of a sequence of ten lidar measurements while the aerosol chamber was operated at a particular (predetermined) opacity value with as nearly uniform particulate concentration as was possible to maintain. While the chamber was in operation, the opacity was monitored continuously by the filtered white-light transmissometer as previously discussed. Each time the lidar was fired, an electronic signal was transmitted to the aerosol chamber which activated the digital printer recording the following information:

- Time of each firing to the nearest second,
- Transmissometer opacity output value,
- Ambient temperature,
- Electrical power to the transmissometer white-light lamp.

Constant telephone communications were provided between the lead-operator of the Omega-1 Lidar and the technician in the control room of the aerosol chamber. The technician told the lidar operator when to begin a data run when the opacity of the particulates within the chamber was stable. The lidar operator would initiate the data run and would continue only if the local atmospheric path along the test range was reasonably stable. Inhomogeneities along this path were caused by small wind gusts blowing ground dust through the area. This occurred in the afternoon hours; so most of the tests were performed from early morning until noon when the air along the range or path was calmest.

A total of 43 data runs were performed with the aerosol chamber opacity values discretely ranging from 0% to greater than 90%. Of these 43 data runs, 13 were discarded and not used because of fugitive dust interference within the lidar's line-of-sight.

The data obtained during the 30 acceptable data runs (251 data values, 49 data values were discarded due to excessive interference of fugitive dust) were processed with the Omega-1 Lidar computer and the software that has been developed, verified and documented for field enforcement use [see Section V].

SRI International analyzed the comparison of the transmissometer's opacity output data recorded by the continuous strip-chart recorder and the digital printer. Out of the entire data set, only 12 data values or points displayed an absolute opacity difference of 5% or greater from one recorder to the other. In analyzing the results of this test series, the nominal opacity value of the printer served as the basis rather than the strip-chart recorder.

Figure VI-4 shows all the lidar opacity measurements plotted as a function of the transmissometer opacity measurements recorded by the digital printer. Also shown is a dashed line representing agreement (equality) between the lidar measurements and the opacity values recorded by the printer. This presentation of the data does not account for any error in the transmissometer measurements or the 5% difference between opacity values recorded by the printer and the stripchart recorder.

A frequency distribution of the differences between the lidar opacity values and the corresponding printer opacity values for all the 251 data points was plotted [Figure VI-5]. The distribution was a normal distribution function. The average lidar opacity, calculated from all the data points, was 0.3% higher than the average opacity of the aerosol chamber. The standard deviation of the distribution was calculated to be about 6%. Therefore, according to this data processing mechanism, the measurement accuracy of the lidar for single measurements of opacity is about ± 6% with

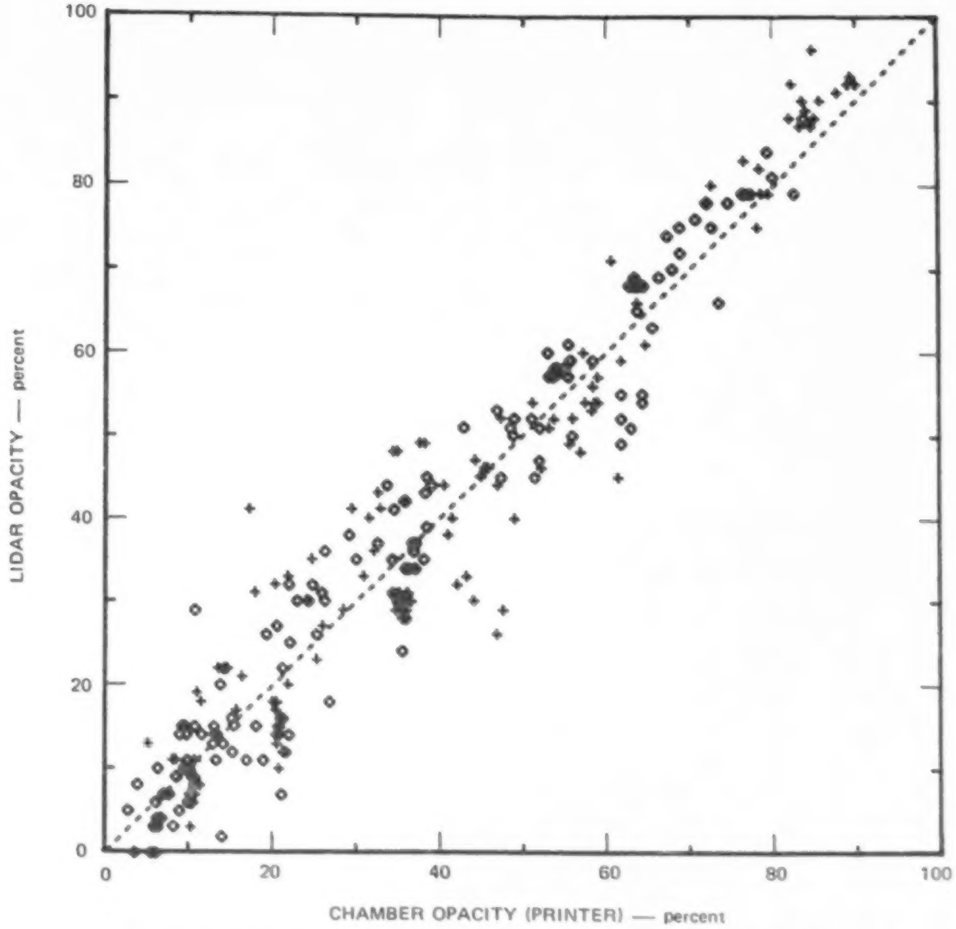


Figure VI-4 LIDAR-DERIVED OPACITY VALUES PLOTTED AGAINST CORRESPONDING TRANSMISSOMETER-OBSERVED OPACITY VALUES [41]

The two symbols represent two different methods of obtaining opacity values from the lidar signature: ◇ based on a reference signature (clean air chamber) and + computed without reference signature (clean air before chamber) — see Appendix B for detail.

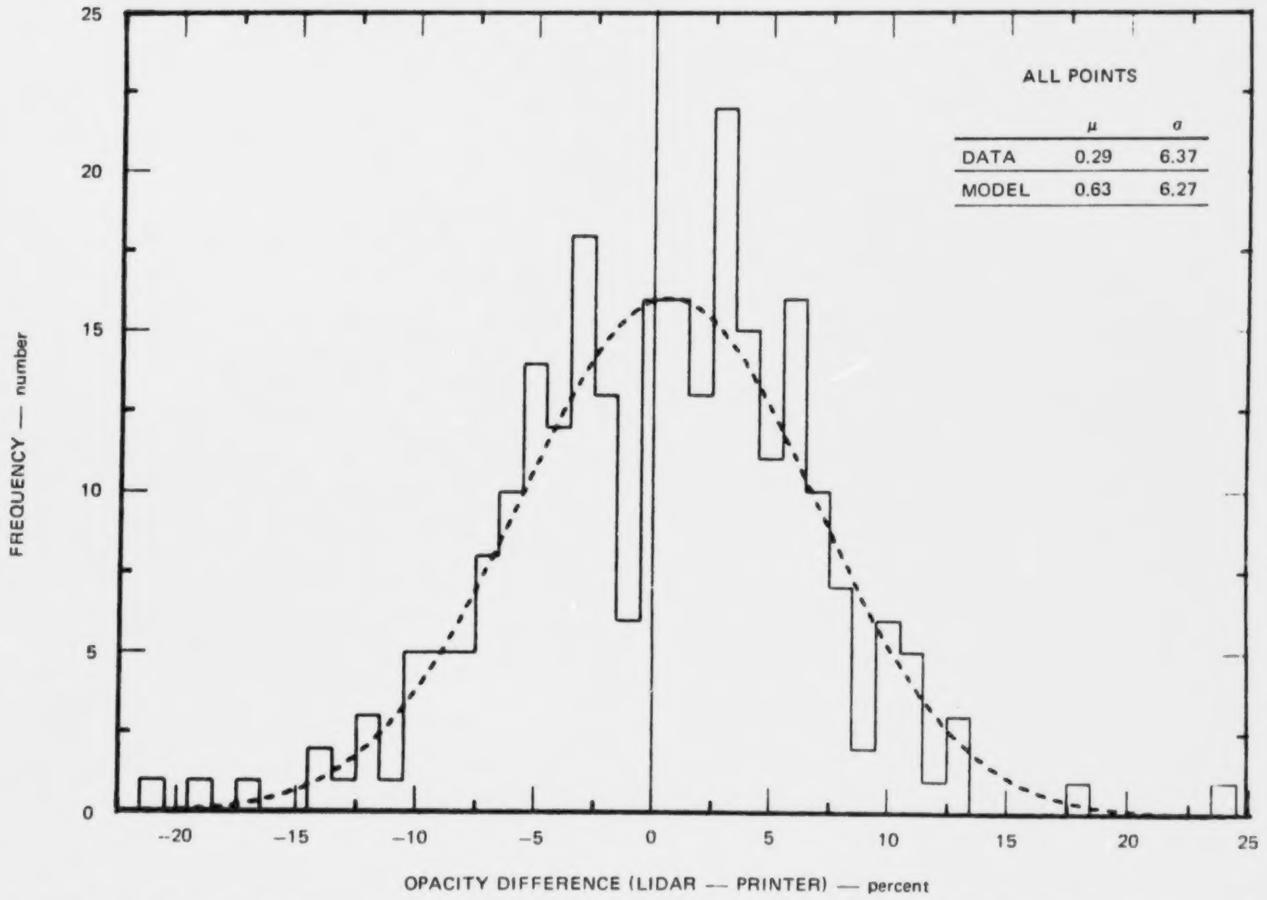


Figure VI-5 FREQUENCY DISTRIBUTION AND BEST-FIT NORMAL DISTRIBUTION FOR THE DIFFERENCE IN LIDAR AND TRANSMISSOMETER-MEASURED OPACITIES (all observations)[41]

a 68% confidence limit and about ± 12% with a 95% confidence limit. The probable error calculated from this distribution is about 4%; i.e., a single lidar measurement in this group of data has a 50% confidence of being within ± 4% of the actual value.

As was stated above, the printer opacity value was assumed to be the basis for the graphic plots and calculations; i.e., there was no accounting for the inherent error in the aerosol chamber's transmissometer and recording equipment. However, there is an error associated with this facility and its measurement of the opacity of the particulates dispersed within the sighting tunnel of the aerosol chamber. In order to see this more clearly, the lidar opacity data and aerosol chamber opacity data for four data runs are presented in Table VI-1. The far-right column in this table is the standard deviation of the measurement of the opacity value as calculated by the lidar computer from the original data collected by the lidar receiver. This gives an indication of the integrity of the lidar return or backscatter signal from the test range.

For example, in Run #13-shot 0, the lidar measured and calculated the aerosol chamber opacity to be 57% with a standard deviation of 1% (the transmissometer measured the opacity to be about 59%). This says that the opacity of the particulates in the aerosol chamber was 57% ± 1% with 68% confidence limits, 57% ± 2% with 95% confidence limits and 57 ± 3% with 99% confidence limits. Run #10, Shot 9, was 69% with a standard deviation of 3%. The latter half of the data in Table VI-1 displays a somewhat larger standard deviation because the effects of the local atmosphere along the test range (via reference measurement or signal) were not normalized out as they were in the first half. This left the atmospheric noise in the calculations of the last half.

The quality and integrity of all the lidar-measured opacity data were reviewed in detail for any errors in calculation, choice of pick intervals (points) [see Section V], and recording of each opacity value in a tabular format. No errors were present. The average standard deviation of the

TABLE VI-1

DATA SAMPLE - AEROSOL CHAMBER TESTS

Run No.	Shot No.	Printer Opacity in %	Lidar Opacity in %	Lidar Opacity Standard Deviation(σ)
13	0	59.1	57.0[a]	1.0
13	1	57.5	54.0	2.0
13	2	57.2	60.0	2.0
13	3	63.7	66.0	2.0
13	4	61.8	59.0	2.0
13	5	59.0	54.0	1.0
13	6	64.7	61.0	2.0
13	7	58.2	53.0	1.0
13	9	55.6	49.0	1.0
16	0	41.5	40.0[a]	2.0
16	1	41.1	38.0	2.0
16	2	45.4	46.0	2.0
16	3	43.2	33.0	2.0
16	4	44.1	30.0	7.0[c]
16	5	46.9	26.0	2.0
16	6	47.6	29.0	3.0
16	7	42.1	32.0	3.0
16	8	40.5	44.0	3.0
16	9	45.8	46.0	2.0
10	0	67.3	74.0[b]	3.0
10	1	77.3	79.0	3.0
10	2	67.9	70.0	3.0
10	3	63.4	69.0	3.0
10	4	79.4	84.0	3.0
10	5	76.4	79.0	3.0
10	6	72.7	75.0	3.0
10	7	70.7	76.0	3.0
10	8	76.4	79.0	2.0
10	9	66.3	69.0	3.0
11	0	55.7	59.0[b]	4.0[c]
11	1	68.9	72.0	3.0
11	2	74.6	78.0	3.0
11	3	72.1	78.0	2.0
11	4	83.8	88.0	2.0
11	5	79.9	81.0	2.0
11	6	68.7	75.0	5.0
11	7	72.1	78.0	2.0
11	8	82.6	79.0	8.0[c]
11	9	73.5	66.0	7.0[c]

[a] Data corrected for atmospheric (clear air) effects in the lidar computer.

[b] Data not corrected for atmospheric effects in the lidar computer.

[c] Large σ due to fugitive dust along the lidar's line-of-sight.

lidar data for all 251 data points was 3.1% as calculated by the lidar computer. (The mean difference between the lidar and the respective chamber-opacity values was 0.3%.) The results of the aerosol chamber tests indicate that the overall standard deviation was about 6%. The difference between these two values lies within the assumption that the printer output of opacity was an absolute basis (opacity value with no associated error) for the entire series of calculations. The errors in the transmissometer's measurement must be taken into account. The inability of the transmissometer to respond to rapid changes (inhomogeneities and particulate kinetics) in actual chamber opacity values must also be considered. The integration time for the transmissometer was about 0.25 seconds. The lidar measured the opacity of the particulates in the sighting tunnel in about 30 nanoseconds; i.e., 30 x 10^{-9} sec, which is 8.3 million times shorter. (The aerosol path through the chamber is about 2 times the laser pulse length.) The transmissometer did not measure opacity along precisely the same path as did the lidar, which is a physical constraint that couldn't be practically eliminated. The standard deviation that may be attributed to the other sources of error, was calculated using the overall standard deviation of 6%, the lidar standard deviation of 3.1% and the fact that the square of the total standard deviation equals the sum of the squares of the lidar standard deviation and the other-error standard deviation ($\sigma_o^2 = \sigma_\iota^2 + \sigma_\varepsilon^2$). The σ_ε may be calculated with the expression $\sigma_\varepsilon = (\sigma_o^2 - \sigma_\iota^2)^{\frac{1}{2}}$. Thus, $\sigma_o = 6\%$, $\sigma_\iota = 3.1\%$ and $\sigma_\varepsilon = 5\%$. The standard deviation of the other errors, given above, is 5%. Thus, if the true opacity in the aerosol chamber's sighting tunnel were 50% (for example), then the output value printed on the digital printer would have a 68% confidence limit of being in the interval of 50 ± 5% and a 95% confidence limit of 50 ± 10%. The lidar measured opacity value would have a 68% confidence limit of being 50 ± 3% and a 95% confidence limit of 50 ± 6%.

INTERNAL CALIBRATION MECHANISM FOR THE OMEGA-1 LIDAR

In order to establish the validity of the particulate plume opacity data obtained with the Omega-1 Lidar, an internal calibration mechanism was designed, fabricated and installed in the lidar's receiver. It is used for testing the overall system performance in the field under conditions, as close as possible to those encountered during real plume measurements. The validity of the lidar opacity data (in enforcement especially) is dependent upon verification that the system was performing as intended at the time the measurements were made. This mechanism evaluates the performance of the lidar receiver independent of the laser transmitter.

The internal calibration mechanism is called an optical signal generator or optical generator [Figure VI-6] [42]. (The optical generator was designed and built by SRI International.) The optical generator uses a highly controlled small solid-state laser (gallium aluminum arsenide) and light-emitting diodes (LED) to inject an optical signal through two fiber optic cables into the receiver ahead of the PMT detector as depicted in Figures VI-7 and VI-8 [42]. The two LED's in the optical generator simulate two functions which are the following:

a. a lidar return signal (representative of atmospheric backscatter) from a usual atmospheric path through clear air; i.e., without any obstructions or visible plumes.

b. a lidar return (representative of plume backscatter) from a smoke plume of various reflectances which is mainly due to particulate density and plume color.

Since the LED was not able to achieve the high-magnitude light levels representative of intense plume return signals encountered with the Omega-1 Lidar in normal operation, the solid state laser was also included as an integral part of the optical generator. It is capable of producing light levels (incident upon the PMT detector) at least 40 dB (four orders of magnitude or 10,000 times) greater than the normal atmospheric optical signal. This strong signal is used during the lidar's performance verification process to check for the adequate recovery of the PMT detector (no afterpulsing) after the simulated plume signal has been shut off, adequate decay

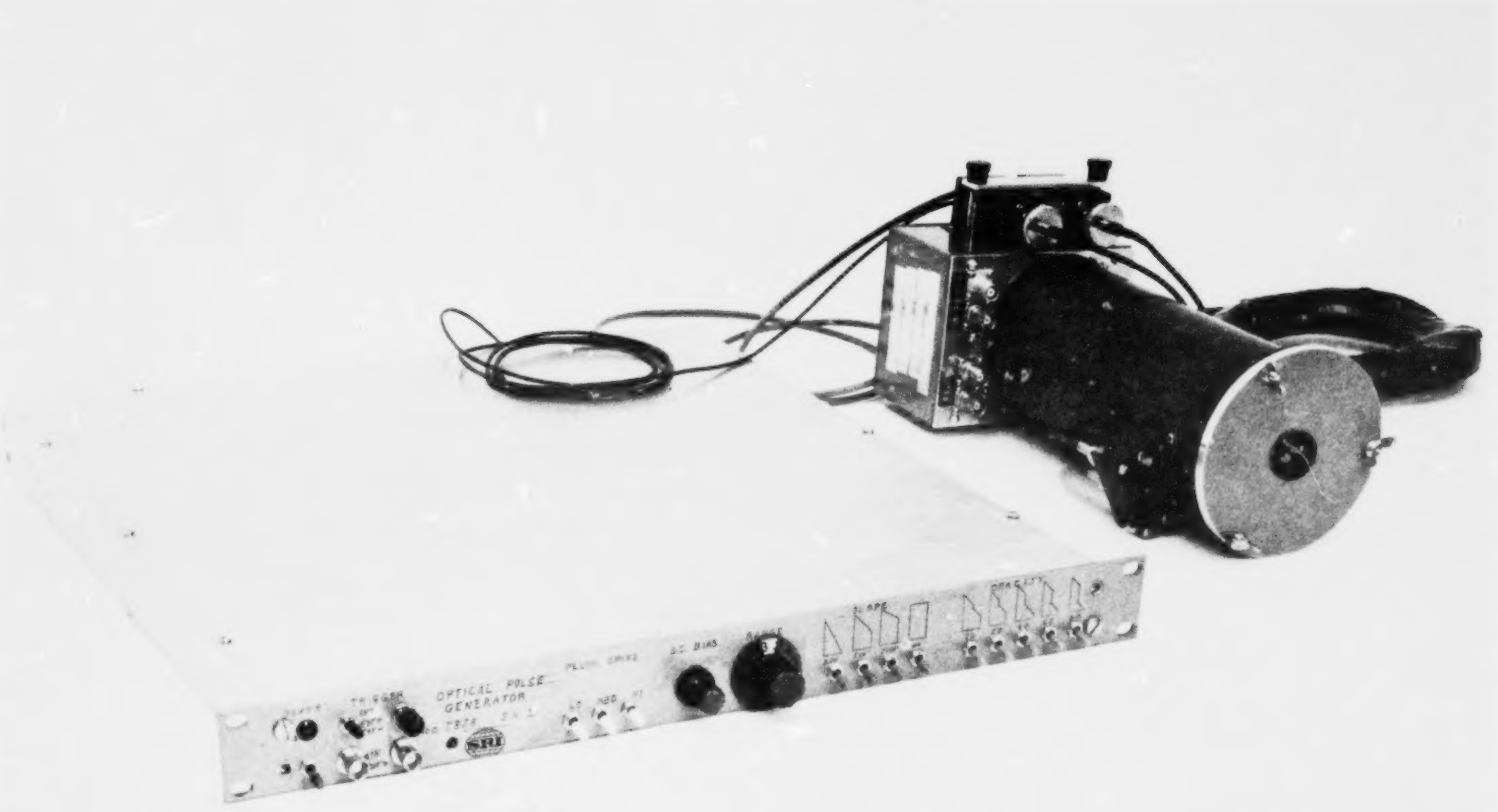

TRIGGER
OPTICAL PULSE
GENERATOR
SRI
D.C. BIAS
RANGE
SLOPE
LO
MED
HI

Figure VI-6 LIDAR OPTICAL PULSE GENERATOR (control unit and two light sources shown coupled to EPA/NEIC PMT assembly)[42]

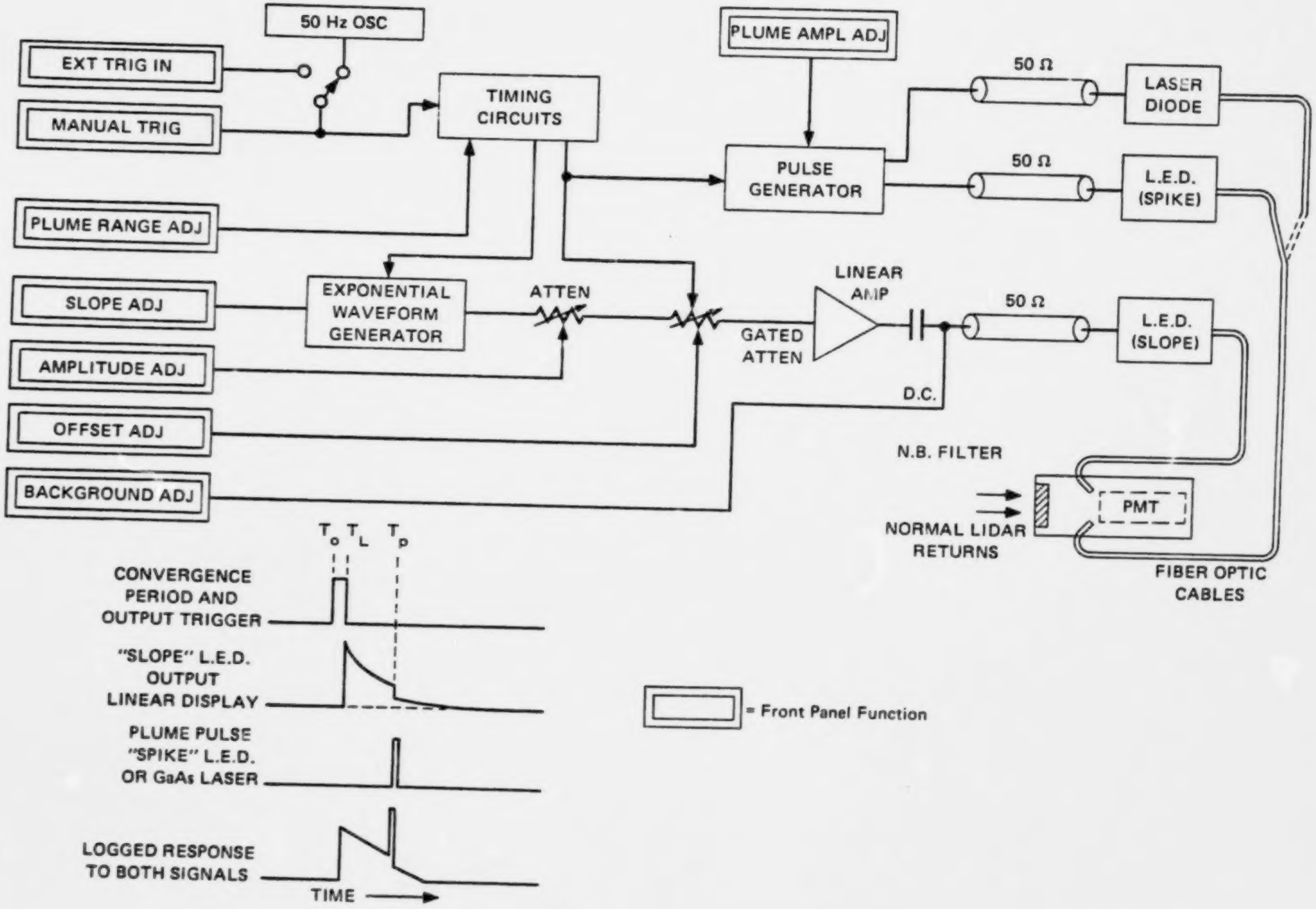

50 Hz OSC
EXT TRIG IN
MANUAL TRIG
TIMING CIRCUITS
PLUME AMPL ADJ
PULSE GENERATOR
50 Ω
LASER DIODE
50 Ω
L.E.D. (SPIKE)
PLUME RANGE ADJ
SLOPE ADJ
EXPONENTIAL WAVEFORM GENERATOR
ATTEN
LINEAR AMP
50 Ω
L.E.D. (SLOPE)
GATED ATTEN
AMPLITUDE ADJ
D.C.
OFFSET ADJ
N.B. FILTER
BACKGROUND ADJ
PMT
NORMAL LIDAR RETURNS
FIBER OPTIC CABLES
T_o T_L T_p
CONVERGENCE PERIOD AND OUTPUT TRIGGER
"SLOPE" L.E.D. OUTPUT LINEAR DISPLAY
= Front Panel Function
PLUME PULSE "SPIKE" L.E.D. OR GaAs LASER
LOGGED RESPONSE TO BOTH SIGNALS
TIME

Figure VI-7 BLOCK DIAGRAM: OPTICAL TEST SIGNAL GENERATOR[42]

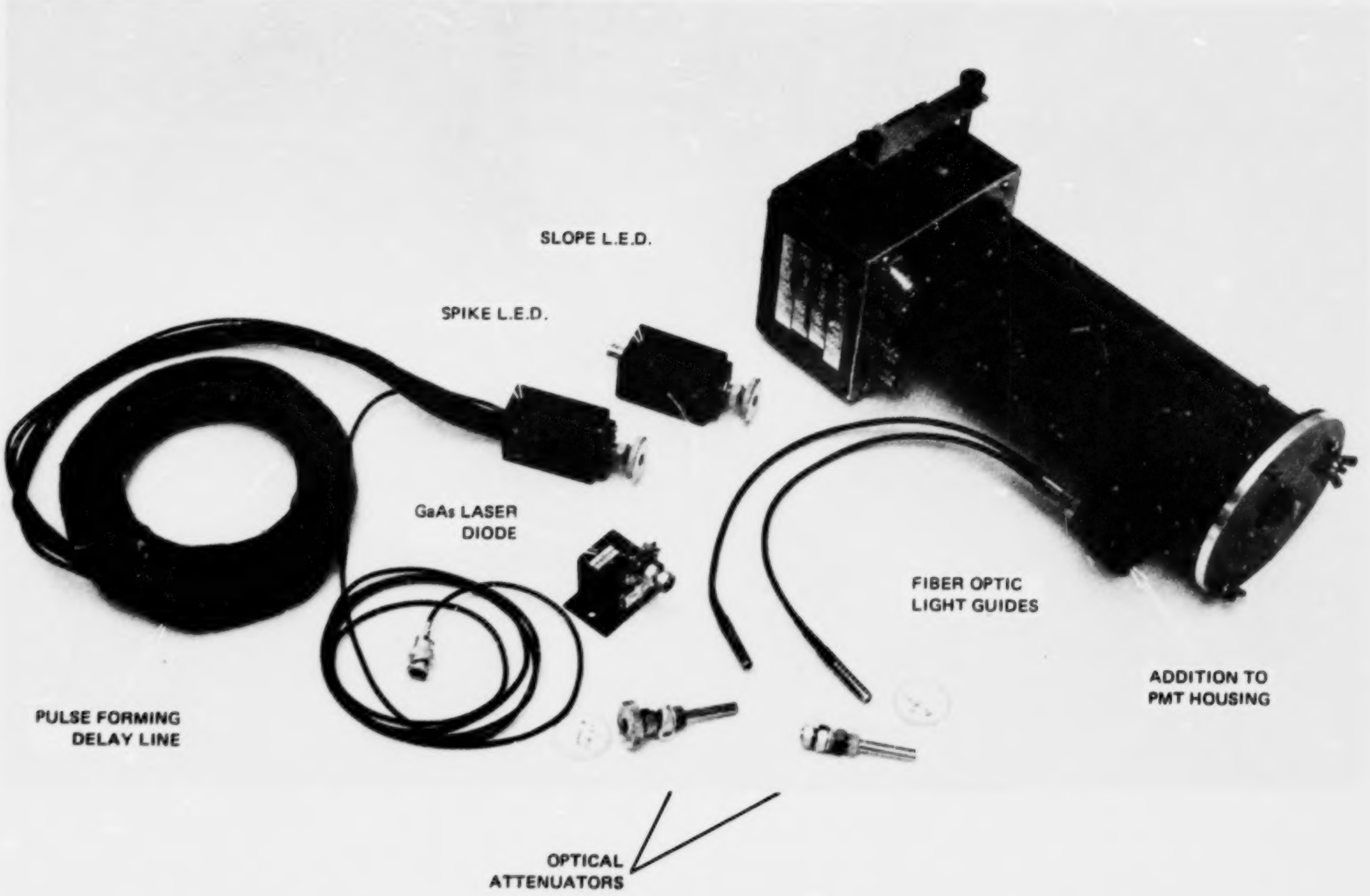

SLOPE L.E.D.
SPIKE L.E.D.
GaAs LASER DIODE
FIBER OPTIC LIGHT GUIDES
ADDITION TO PMT HOUSING
PULSE FORMING DELAY LINE
OPTICAL ATTENUATORS

Figure VI-8 LIGHT SOURCES AND OPTICAL COMPONENTS[42]

times and any memory or residual effects in the receiver or electronics (linear or logarithmic channels) after the simulated plume signal has been shut off. The simulated plume is electronically movable in range from a minimum value of 76 meters (250 feet) continuously out to a maximum range at 760 meters (2,500 ft).

The optical generator simulates lidar signals (plume and atmospheric backscatter) corrected for $1/R^2$ or in the uncorrected form [Section IV]. The uncorrected simulated signal (linear channel) for a clear-air atmospheric backscatter return signal is shown in Figure VI-9 and the $1/R^2$ corrected signal is given in Figure VI-10.

The optical generator simulates real optical backscatter (atmosphere and plume) signals representing opacity values for various plumes. The opacity values are 0% (clear-air), 10, 20, 40, 60 and 80% (nominal). The simulation is performed for both the linear and the logarithmic channels.

The optical generator was subjected to an exacting calibration at NEIC. All signal levels, used in the opacity calculations, were measured to within a fraction of a percent of the actual values. The precise value of each discrete (nominal) opacity value; i.e., 0, 10, 20, 40, 60, and 80%, was measured. They were as follows:

Table VI-2

LATEST OPTICAL GENERATOR CALIBRATION TEST RESULTS[a]

Nominal Opacity (%)	Calibrated (measured) Opacity (%)	Standard Deviation (%)
0	0.60	0.34
10	10.72	0.24
20	19.72	0.27
40	40.42	0.22
60	62.97	0.31
80	79.80	0.54

a February 1981

The optical generator is periodically subjected to this exacting calibration in which all the necessary signal levels are measured and the respective opacity value calculated to within a fraction of a percent.

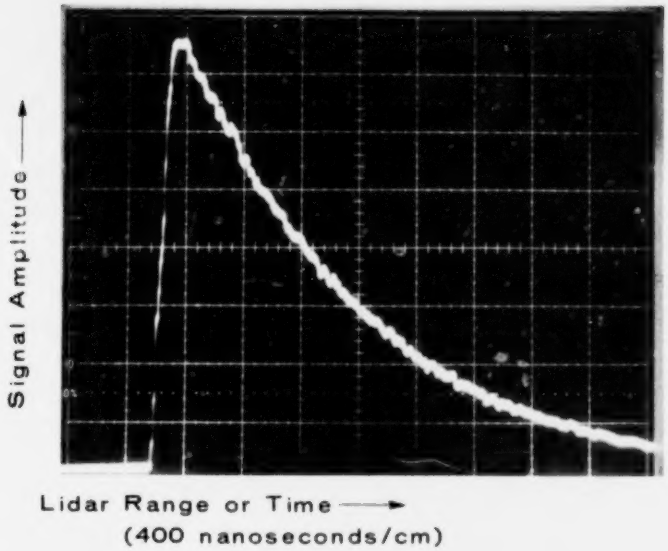


Figure VI-9 Lidar Atmospheric Backscatter Signal (clear-air), Uncorrected For $1/R^2$ (Optical Generator)

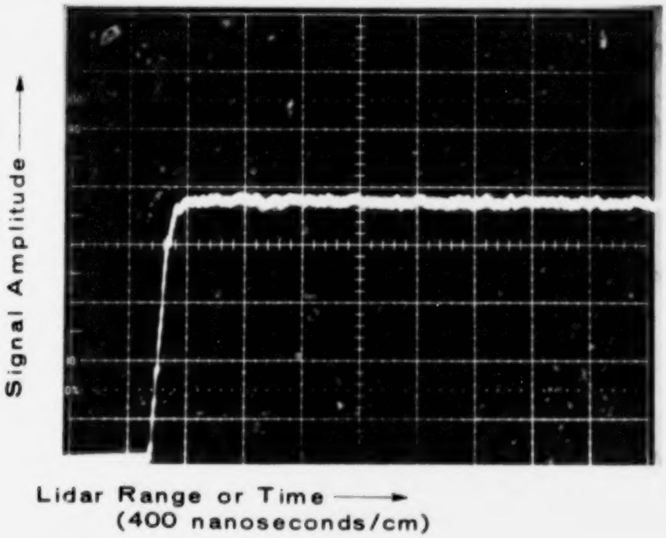


Figure VI-10 Lidar Atmospheric Backscatter Signal (clear-air), Corrected For $1/R^2$ (Optical Generator)

CORRECTIVE ACTION PERFORMED ON THE OMEGA-1 LIDAR

After the aerosol chamber tests and the optical generator evaluation were completed, the Omega-1 Lidar was returned to Denver. NEIC personnel began the task of correcting the problems that were encountered during the SRI tests. Each problem will now be briefly discussed along with the corrective action performed.

Electromagnetic Interference (EMI)

The problem of EMI from the laser's Pockel Cell Q-Switch was discovered during the aerosol chamber tests at SRI International [Section VI.A.]. The problem was temporarily fixed at SRI. Once back in Denver remedial action was taken to permanently fix the problem.

All Q-Switch power supply and remote control cable wiring was completely rerouted away from the electronic signal cable which carries the video signals from the photomultiplier detector to the linear and logarthmic processing electronics located in the equipment rack in the computer room. The video cable (double-shielded) was also rerouted to the equipment rack. The shields were terminated to ground at both ends. The high voltage cables (two coaxial cables) from the Q-switch, located in the laser's optical rails, were twisted and a permanent shield added and terminated to ground at both ends. Also the Q-Switch was returned to the supplier and reworked. It had a KDP (potassium dihydrogen phosphate) optical crystal (electro-optical modulator) which required 15,000 volts DC to fully energize. This crystal was changed to a KD*P (potassium dideuterium phosphate) crystal requiring 6,500 volts DC for full operation. The new crystal provided the same operational characteristics in the Q-Switch with significantly lower electrical transfer energy. This also decreased the amount of EMI present within the system.

Once all these modifications were completed, the entire lidar receiver was tested using the precision signals of the optical generator as a source for the PMT.

Before the modification, the EMI noise occurred over an interval of 160 nanoseconds from time-value 230 nanoseconds into the receiver's turn-on cycle to time-value 390 nanoseconds as shown in Figure VI-11.

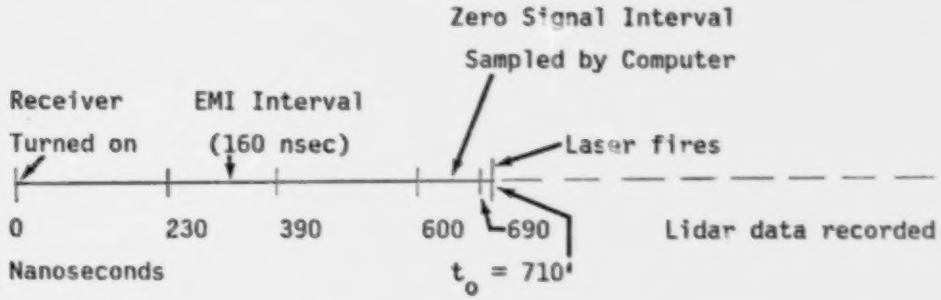


Figure VI-11
Lidar Receiver Time Cycle (each shot)

The optical generator tests, with the Q-Switch system electronics operting, revealed that the EMI noise level was reduced to the level of the inherent receiver noise which is always present in the interval from 0 nanosec to 710 nanosec, when the laser fires. Also the optical generator signals were turned off (atmospheric backscatter simulation signal and the plume spike signal) and the receiver was tested at the zero-signal level throughout the entire lidar time intervals of 4 microseconds and 10 microseconds. There was no evidence of EMI noise present. Then the entire lidar system was operated with the laser fired into the atmosphere. No EMI noise above the inherent zero-signal level was present in the receiver. Thus, the EMI problem was successfully corrected.

Laser Beam Pattern

During the aerosol chamber tests, a noticeable amount of laser energy in the first secondary maximum, that surrounded the intense central spot of the laser beam, was detected. This resulted in a significant reflection signal from the front surface of the aerosol chamber. At SRI the optical train of the laser was in alignment. It was concluded that the upcollimator would have to be refocused and realigned within the optical rails of the laser.

The upcollimator was removed from the laser assembly and taken to the NEIC Optics Laboratory. It was disassembled and carefully cleaned. The inside of the upcollimator was bare, shiny metal, and it was sprayed with a flat black paint. The upcollimator was again assembled and prepared for focus adjustments. The assembly was focused using a 5-milliwatt He-Ne laser being aimed down a hallway about 500 feet in length. The focus adjustment was carried out to achieve minimum beam divergence (beam spread over distance). The measured beam divergence was slightly less than 0.2 milliradians. Once this was achieved the focus mechanism was locked in place in order to prevent any further inadvertent adjustment.

The upcollimator was placed in its proper position at the front of the laser's invar rails and aligned so that the laser beam would propagate down the assembly's principal axis which was not the case before focusing. Diagnostic tests were performed by aiming and firing the lidar at a smoke generator without the smoke being present. The intense central beam was brought very close to the lip of the stack without actually hitting the stack, and there was no reflective return signal observed with the lidar receiver. The corrective action was successful.

Lidar Receiver Detailed Performance Evaluation

With the optical generator permanently installed and fully calibrated (Table VI-2), the entire lidar receiver was subjected to a precise performance evaluation. The performance evaluation tests of the linear video channel and the logarithmic video channel were conducted separately.

Linear channel

The results and conclusions for the linear channel of the lidar's receiver and signal processing system are now presented. First, the performance of the photomultiplier (PMT) detector was verified again. (The performance of the PMT was evaluated by SRI International during the aerosol chamber tests.)

The PMT was checked for gain linearity as a function of its high-voltage ranging from 1.0 KVDC to 2.9 KVDC. The results of these tests are presented in Figure VI-12. The gain is linear throughout the high voltage range. This is especially true for high voltage values below 2.3 KVDC which is the normal operating range for the PMT in the lidar's field use.

The performance evaluation of the linear channel was conducted using the optical generator as the input optical signal. The opacity values from 0 through 80% (nominal, see Table VI-2) were measured as a function of PMT high voltage from 1.0 KVDC through 2.9 KVDC in 100 volt steps or incre ments. Each opacity value was calculated 24 times for each opacity selection on the optical generator and PMT high voltage setting. The opacity values of 0, 10, 20, 40, 60 and 80% were measured for each PMT high voltage setting. A total of 2,880 opacity calculations were performed. All these data were analyzed in the lidar's computer.

The results, summarized together; i.e., all opacity values over the entire PMT high voltage range, revealed that the lidar's linear channel consistently measures and computes opacity to within approximately 1% of the calibrated value (actual values: mean difference of 0.2% with a standard deviation of 0.6% based on 2,880 opacity values).

The correlation of measured opacity values (0 to 80% nominal) to the respective calibrated (optical generator) values as a function of PMT high voltage settings was calculated. The results are given in Table VI-3.

Table VI-3

LINEAR CHANNEL EVALUATION TEST RESULTS[a]

Optical Generator Nominal Opacity (%)	Difference from Calibrated Value (%)	Standard Deviation (%)
0	-0.1	0.1
10	+0.1	0.3
20	+0.3	0.3
40	+0.2	0.4
60	-0.6	0.8
→ 80	-1.9	0.6 ←

[a] PMT High-Voltage Operating Range: 1.0 to 2.9 KVDC.

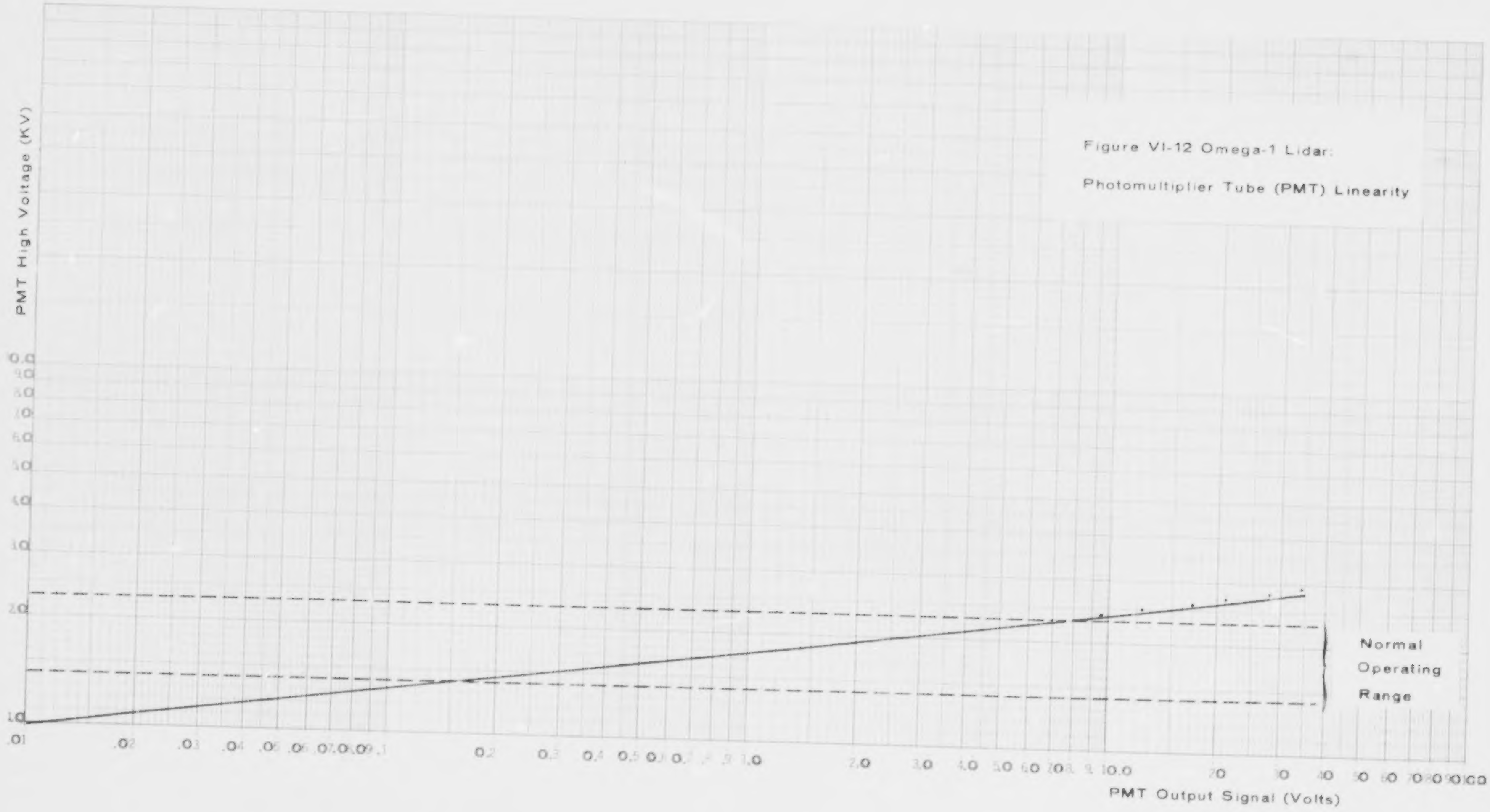


Figure VI-12 Omega-1 Lidar:
Photomultiplier Tube (PMT) Linearity

The 80% value in Table VI-3 has the largest deviation from the optical generator's calibrated value (-1.9%). This is due to the larger inherent error in the linear channel at high opacity values as depicted in Figure V-7.

Logarithmic Channel

During the performance evaluation tests at SRI International, the logarithmic video amplifier was also subjected to tests. When driven with a clean exponentially decaying signal the output signal of the logarithmic amplifier should have been a smooth linear ramp. However, there was a noticeable offset in this linear ramp as viewed on the lidar oscilloscope. This offset occurred about midway in the amplitude range of the linear ramp. This electronic artifact was not investigated further at SRI.

When the lidar had been returned to Denver, diagnostic tests were carried out on the log amplifier. The source of the offset was isolated to a capacitor not performing properly. This problem was corrected and the tests resumed. The electronic artifact was fully corrected.

A linearity check was performed on the output signal of the logarithmic amplifier (exponentially decaying signal as the input signal). The output was linear to within 0.53 dB (decibel) of the ideal linear signal. The specifications given by the manufacturer listed the linearity as "less than 1.0 dB." The total dynamic range of this amplifier is 100 dB (10 decades) and the linearity is about 0.5% of this range.

The performance evaluation of the logarithmic channel was also conducted using the optical generator as the input optical signal for the lidar receiver. The opacity values from 0 through 80% (nominal) were measured as a function of PMT high voltage from 1.3 KVDC through 2.1 KVDC in 100 volt increments. The same procedure was used as for the linear channel. The opacity values of 0, 10, 20, 40, 60 and 80% were measured 25 times for each PMT high voltage setting. A total of 1,950 opacity calculations were performed. These data were analyzed in the lidar's computer.

The results of the opacity data analysis yielded the following:

Table VI-4

LOGARITHMIC CHANNEL EVALUATION TEST RESULTS[a]

Optical Generator Nominal Opacity (%)	Difference from Calibrated Value (%)	Standard Deviation (%)
0	-6.6	0.5
10	-2.2	0.5
→ 20	+0.2	0.5 ←
40	+0.1	0.3
60	-0.3	0.4
80	-0.2	0.4

[a] PMT High-Voltage Operating Range: 1.5 to 2.1 KVDC (normal).

These data clearly indicate that the lidar's logarithmic channel consistently measures and calculates opacity to within 1% of the calibrated value for the opacity range from 20 through 80% (the mean difference ranged from -0.3 to +0.1% with a maximum standard deviation of 0.5% based on 1,950 opacity values).

The logarithmic channel gives rise to a significant negative error (calculates opacity to be less than the actual values) at 10 and 0% or clear air. As discussed in Section V of this report, this channel was designed for use in quantitative measurement of opacity values greater than 40% and in atmospheric conditions of heavy particulate burden or loading. The logarithmic channel is not used for opacities below 40% in the field. The linear channel is more accurate at low opacity values.

FIELD EXPERIMENTATION

The Omega-1 Lidar has been subjected to four different tests for the direct determination of actual/simulated plume opacity. The tests performed were the following:

- Screen Target Test,
- Statistical Covariance Test,
- Colorado Smoke Generator Test,
- Lidar - Reference Method 9 Collaborative Test.

The results and conclusions of these tests are presented in the following subsections.

Screen Target Test

This test was conducted in the Denver, Colorado area using four screen targets of different size mesh. The screens were used to simulate a smoke-plume of constant opacity. The screen material ranging from hailscreen to fine window screen, is securely attached to a wooden/metal frame measuring about 1 meter square (1 square meter screen area). The opacity of each screen assembly was determined in the laboratory at NEIC. The opacity values ranged from 30.9 to 75.8% for the four screens. The actual values are given in Table VI-5.

The purpose of the test was to determine how precisely and accurately the lidar could measure the fixed opacity value of each screen along with clear air (no screen) for 0% opacity. The optical generator tests discussed earlier in this section evaluated the performance of the entire lidar receiver, but did not include the laser transmitter and the atmospheric environment. The screen tests included the entire lidar system.

During this test, the screen assemblies were mounted one at a time on a support leg of a tall water storage tower by means of an aluminum screen holder. The holder and screen were about 45 feet above ground level to avoid interference of the ground effect of blowing dust particles. The lidar was about 300 meters (1,000 ft) from the water tower.

With all the metal structure contained in the test set-up, the lidar was fired through the empty (square) screen holder for 45 shots. The resultant average opacity of the empty holder was determined to be 1.3% (column 3 of Table VI-5). The lidar measured the opacity of screen #1 for 245 shots with an average opacity of 46.1% (column 3). The laboratory-measured opacity of the screen is 45.5% (column 5). The average difference is +0.6% (column 8) for the lidar value with respect to the screen. The absolute precision of the lidar-measured opacity, 46.1%, for this screen

Table VI-5

SCREEN TARGET AND STATISTICAL COVARIANCE TEST RESULTS

Target Along Lidar Line of Site (1)	Length of Run: No. of Lidar Shots (2)	Average Opacity (%): $\bar{O}_p$ (Lidar) (3)	Standard Deviation of $\bar{O}_p$'s (%) (4)	Screen Opacity (%): $\bar{O}_p$ (Screen) (5)	$\bar{S}_o$ (%) With Covariance (6)	$\bar{S}_o$ (%) No Covariance (7)	Average Difference: $\bar{O}_p$ (Lidar) Minus $\bar{O}_p$ (Screen) (8)
Empty Screen Holder (A1)	45	1.3	1.95	0.0	1.7	2.1	+1.3
Screen #1	245	46.1	4.26	45.5	1.0	1.1	+0.6
Screen #2	240	30.7	3.02	30.9	1.1	1.1	-0.2
Screen #3	230	66.2	2.43	64.7	0.6	0.6	+1.5
Screen #4	250	74.7	1.46	75.8	0.4	0.4	-1.1
Clear Air Straight-up	100	0	0.89	-	1.1	1.2	-

Notes:

$\bar{O}_p$ - Average opacity

$\bar{S}_o$ - Average standard deviation calculated from the lidar data, Equation (V-15).

was 1.0% (column 6). The results for the remaining three screens are presented in Table VI-5. Referring to Column 8 of Table VI-5 the average difference in opacity ranged from -1.1 to 1.5%. The absolute precision ranged from 0.4% to 1.1% (column 6). In addition, 100 clear-air shots were recorded with the lidar aimed vertically yielding an average opacity of 0% (column 3) with the pick intervals positioned about 75 meters apart.

This test clearly shows that the lidar measures opacity along an atmospheric path precisely with consistent accuracy and nonsubjectivity. The larger average difference of this test with respect to the optical generator test is due to the presence of atmospheric backscatter signal noise, caused by wind-blown dust passing through the lidar's line of sight.

Statistical Covariance Test

This test was conducted using the screen test data to show that the assumption that the covariance terms in Equations (V-10) and (V-13) would sum to zero in the lidar data analysis calculation of S_o was correct. During the computer analysis of the lidar data obtained from constant opacity targets, S_o was calculated using both Equation (V-10) including the covariance terms and Equation (V-15) with the covariance terms removed. The average values of both S_o parameters, S_o with covariance terms and S_o with no covariance terms, were calculated and the results are presented in Table VI-5, Columns 6 and 7. From 0 to 75.8% opacity, the $\bar{S}_o$ values in column 7 are equal to or greater than those in column 6 in all cases. These data show that the values for $\bar{S}_o$ calculated using Equation (V-15) with the sum of the covariance terms set to zero, are equal to or larger than the values for $\bar{S}_o$ calculated using Equation (V-10) with the covariance terms included. (Analysis of all the individual standard deviation values for the four screens and clear air showed that S_o, with no covariance terms, was greater than or equal to the corresponding S_o with covariance terms for 71% of the total number of values.) Equation (V-15) for S_o is the one used to calculate the standard deviation for each lidar plume data signal analyzed, and reported with its respective opacity value O_p. The calculations performed using Equation (V-15) require significantly less computer time than those associated with Equation (V-10).

Colorado Smoke Generator Test

The smoke generator located at Camp George West in Golden, Colorado, was used as a stationary source of particulate emissions for the lidar. A total of 23 opacity monitoring runs using both black (21 runs) and white (2 runs) smoke were conducted. Some of the runs were conducted when the plume and localized atmospheric conditions were reasonably stable. (The smoke generator test site is located at the foot of South Table Mountain and wind conditions of 20 to 30 knots are not uncommon.) The remainder of the runs were carried out under windy conditions when the generator's plume was moving at a right angle to the lidar's line-of-sight (l.o.s) or downwind along the l.o.s. Under the latter condition, the plume was fumigating the l.o.s.

The purpose of these tests was to provide field operating experience to the operating personnel under widely varied conditions with control over the opacity of the smoke, and to provide a comparison between the opacity values measured by the lidar and those measured by the smoke generator's transmissometer.

The smoke generator has a white light (tungsten lamp) transmissometer located about halfway up its 5 meter stack having a diameter of 1 foot. It has an electronic integration time of about 5 to 7 seconds. It responds slowly to changes in plume opacity in the stack. The lidar measures the opacity of the plume, just above the stack, in about 15 nanoseconds (1 nanosecond = 10^{-9} seconds; the transmissometer's measurement time is $4 \cdot 10^{8}$ times longer than that of the lidar) which is essentially instantaneous.

The transmissometer was used as a monitor in order to adjust the opacity of the black and white smoke. Because of the lengthy electronic integration time of the transmissometer it would lag in indicated opacity value behind that actually present in the generator's stack. As a result if the opacity were raised from 40 to 80% gradually, the lidar would measure the opacity at any given time more precisely than would the transmissometer.

The smoke generator was, for the most part, not a source of constant opacity plumes. Plume opacity would fluctuate (visually observed) or become erratic during the tests. The smoke generator's opacity values were limited to the range from 0% to about 75%. Above this range the generator was quite unstable and the transmissometer's output was difficult to read with reasonable accuracy. Also, it was observed that the plume opacity would always fluctuate when the wind was blowing.

The data recorded during this test were subsequently analyzed on the NEIC laboratory computer [Appendix B(b)]. Each of the 23 data runs (linear video channel data) was a minimum of 5 minutes (30 opacity measurements or data points) in length. The average opacity values $\bar{O}_p$ from the lidar and the smoke generator's transmissometer are recorded in Table VI-6 along with the average difference of each data run.

The standard deviation (σ) indicates the amount of variability of the plume opacity values for each data run. A standard deviation of 1.58% indicates a reasonably stable plume while the data points were being recorded, while a standard deviation of 6.94% shows that the plume variability was high.

The analyzed opacity data show that the lidar average opacity values ranged from 0% average difference to -3% (lower) with respect to the smoke generator transmissometer for 83% of the 23 data runs. All the average difference values were between 0 to -6%, or the lidar average opacity was always less than or equal to the average opacity from the generator's transmissometer. Twenty-one of the data runs were conducted using black smoke while the other two were with white smoke.

The mean-average difference, the average of the values in Column 6 of Table VI-6, was calculated to be -2%. The negative average difference is primarily due to the fact that the optical extinction for white light is slightly greater than that for red light.

Table VI-6

COLORADO SMOKE GENERATOR TEST
LIDAR VS SMOKE GENERATOR OPACITY TEST RESULTS

Omega-1 Lidar			CO Smoke Generator		
Average Opacity (%): $\bar{O}_p$ (Lidar)	σ_L(%)	Average Standard Deviation: $\bar{S}_o$(%)	Average Opacity (%) $\bar{O}_p$(Sm. Gen.)	σ_{sg}(%)	Average Opacity Difference: $\bar{O}_p$(Lidar) minus $\bar{O}_p$(Sm. Gen.) (%)
0	1.30	1.5	0	0.00	0
2	2.26	2.5	4	0.55	-2
3	1.58	2.0	5	0.77	-2
8	2.95	2.1	10	0.31	-2
8	2.41	2.0	10	0.41	-2
9	4.30	2.3	10	0.38	-1
10	4.02	2.5	11	1.10	-1
17	4.02	2.7	20	1.74	-3
17	3.47	2.1	20	0.92	-3
19	6.27	2.7	19	3.83	0
19	3.20	1.5	20	0.49	-1
22	1.78	2.1	28	0.65	-6
30	6.94	2.1	33	3.14	-3
32	3.44	1.6	32	1.48	0
32	6.29	3.0	32	4.52	0
36	4.28	1.2	39	2.54	-3
41	5.12	2.2	41	2.41	0
48	5.02	1.5	52	3.46	-4
54	4.29	2.1	55	2.36	-1
59	6.40	2.7	60	3.01	-1
62	5.24	1.2	63	1.22	-1
68	3.74	1.3	72	1.20	-4
69	2.62	2.2	74	2.31	-5

Notes:

$\bar{O}_p$ - Average Opacity

$\bar{S}_o$ - Average standard deviation calculated from the lidar data, Equation (V-15).

σ - Standard deviation calculated from the individual opacity values, O_p.

The average opacity values determined by lidar (column 1 of Table VI-6) and those from the smoke generator's transmissometer (column 4 of Table VI-6) were plotted for each oof the 23 data runs. The graphical plot of these values is presented in Figure VI-13. The sequential data runs are presented along the graph's abscissa while opacity (%) is given along the ordinate. The individual oapcity values are connected by red and blue lines for ease of reading and interpreting the plot, and do not imply a continuous functional relationship. This plot clearly shows that the lidar average opacity values are less than or equal to those respective values obtained from the smoke generator's transmissometer.

Figure VI-14 is a correlation plot of the columns 1 and 4 of Table VI-6. The smoke generator average opacity values are plotted along the abscissa and the lidar average opacity values are plotted along the ordinate. The blue line is the equality line, $\bar{O}_p$ (lidar) = $\bar{O}_p$ (smoke generator). The green line is the mean average difference line which has the magnitude of -2% as discussed above. The red line connects the corresponding points positioned by plotting $\bar{O}_p$ (lidar) vs $\bar{O}_p$ (smoke generator); however, functional dependence is not implied between the plotted points. The plotted points with the adjacent (2) indicates two identical values from Table VI-6. were plotted at these respective positions. All the points of the red line being on or to the right of the blue equality line indicates that the lidar average opacity values are less than or equal to the respective smoke generator average opacity values.

In Figure VI-15 the individual opacity values measured by lidar (red line) and those measured by the smoke generator transmissometer (blue line) are plotted with respect to local time. The blue and red lines between the describe points are included for readers' ease of reading the plot and do not imply any functional relationship or dependence between the points. The effect of the transmissometer's long electronic integration time is easily observed. The transmissometer was tracking the larger changes in plume opacity; however, there was a significant lag time with respect to the lidar data. This transmissometer was not able to measure the rapid change in opacity, but rather tended to average these rapid opacity changes.

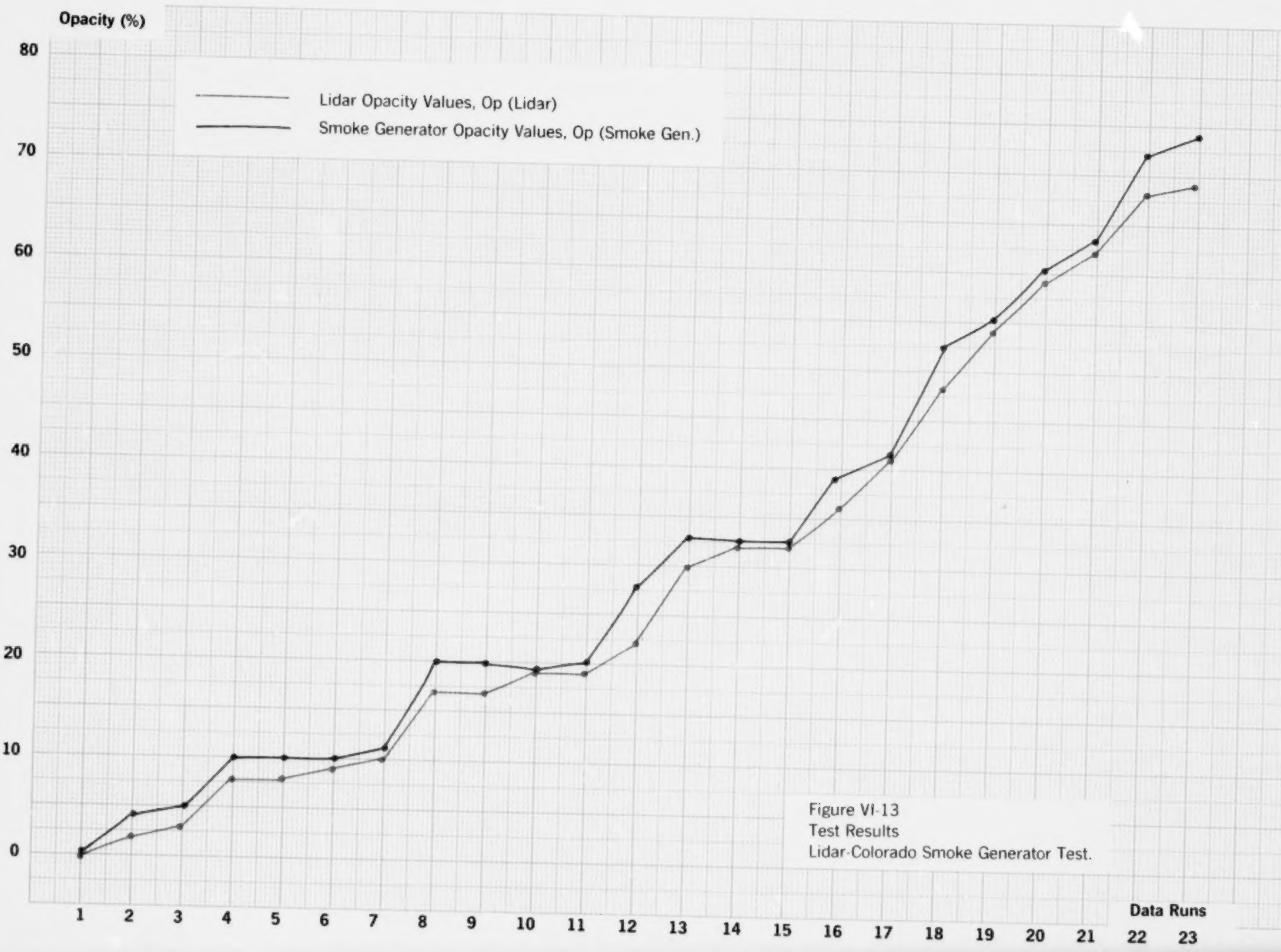


Figure VI-13
Test Results
Lidar-Colorado Smoke Generator Test.

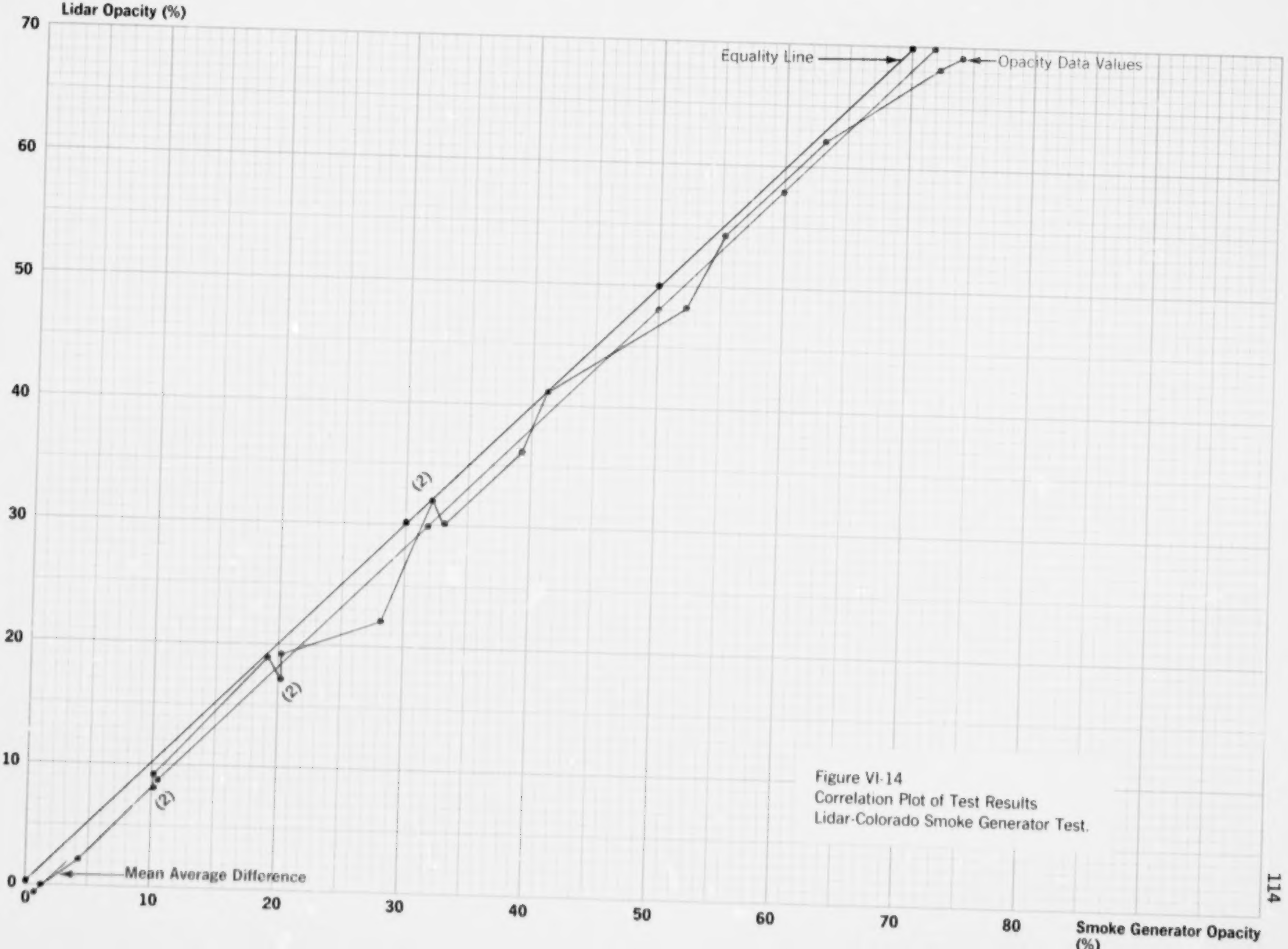


Figure VI-14
Correlation Plot of Test Results
Lidar-Colorado Smoke Generator Test.

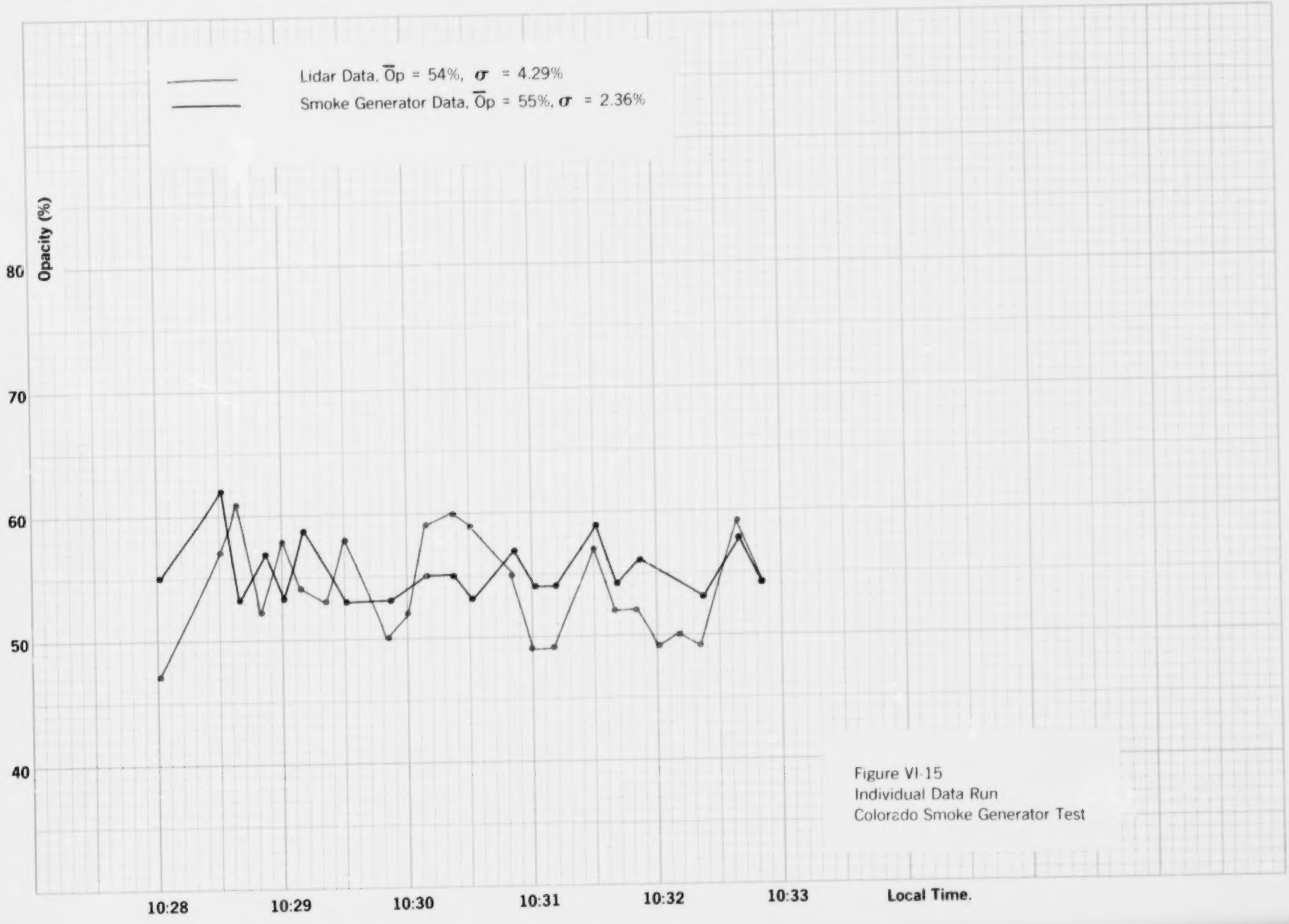


Figure VI-15
Individual Data Run
Colorado Smoke Generator Test

In Figure VI-15, the lidar plume opacity values ranged from 47 to 61% while those from the transmissometer ranged from 53 to 62%. Even with the high plume variability the average opacity over the 5-minute time interval was 54% for the lidar and 55% for the transmissometer.

Lidar-Reference Method 9 Collaborative Test

The colloborative test was conducted in Austin, Texas using the Texas Air Control Board (TACB) smoke generator. The purpose of the test was to document the relationship between opacity values as measured by lidar and those recorded by visible emissions observers. If any bias, positive or negative, were present, this test was designed to define the magnitude of the bias for black and white smoke.

The TACB smoke generator was positioned in one corner of a large rectangular field and the Omega-1 Lidar was set up near the opposite corner of the field. The lidar was about 215 meters (700 ft) from the smoke generator. At this distance the diameter of the intense central spot of the laser beam was about 8 cm while the plume diameter was slightly over 30 cm.

The testing regime was divided into two parts with one being for black smoke and the other for white smoke. The TACB furnished two teams of three certified visible emissions observers.

The test consisted of 20 data runs for black smoke and 14 data runs for white smoke. Each data run contained 25 opacity values which were obtained according to the procedures of Method 9 with the exception of the temporal cycle. About one fourth of the data runs were conducted on a 15-second cycle while the remainder were on a 10-second cycle. The operator of the smoke generator sounded the horn (used for smoke school) on the 10- or 15-second intervals. At the time the horn was heard one team of three visible emissions observers read the opacity of the smoke. The horn was patched by UHF radio to the lidar. When the horn signal was heard in the lidar, the laser was fired. The opacity value selected for each data run was selected by the smoke generator operator without the knowledge of the visible emissions observers. The smoke generator operator randomly selected the particular opacity value for the smoke just prior to each run, i.e. values were selected in no order or sequence. A dual set of records was kept throughout the test. One set was kept at the smoke generator and the other set at the lidar. Just prior to each run, the generator operator called the chosen initial opacity value and the sequential run number to the lidar with the UHF radio where they were recorded in the lidar operations log book. During the data runs, an EPA technician recorded the smoke generator transmissometer opacity values (not kept constant but varied throughout the data run) from the control panel display, in a bound log book each time the horn was sounded.

The test was conducted over a time span of 1½ days from mid-morning through late afternoon. The wind blew about 5 to 15 Km/hr throughout the entire test period. The two crews of visible emission observers alternated duty from one data run to the next.

The lidar A-scope data (backscatter return signal) was recorded on a magnetic data tape for each shot of each data run. These data were subsequently analyzed on the NEIC laboratory computer [Appendix B(b)]. The opacity values obtained with lidar, visible emissions observers and the smoke generator's transmissometer were recorded on a data reduction sheet for each of the 25 values for each data run. The average and standard deviation (opacity value scatter) were calculated for the following parameters:

- Lidar opacity values → $\bar{O}_p$(lidar), σ_L
- Standard deviation values, S_o → $\bar{S}_o$
- Smoke generator opacity values → $\bar{O}_p$ (smoke generator), $\sigma_{s.g.}$
- VEO #1 opacity values → $\bar{O}_p$ (VEO #1), σ_1
- VEO #2 opacity values → $\bar{O}_p$ (VEO #2), σ_2
- VEO #3 opacity values → $\bar{O}_p$ (VEO #3), σ_3
- $\bar{O}_p$ (VEO #1), $\bar{O}_p$ (VEO #2), and $\bar{O}_p$ (VEO #3) → $\bar{O}_p$ ($\overline{\text{VEO}}$)

These average values for each respective black smoke data run are recorded in Table VI-7. The average difference of opacity values,

1) $\bar{O}_p$ (Lidar) - $\bar{O}_p$ (Smoke Generator),
2) $\bar{O}_p$ ($\overline{\text{VEO}}$) - $\bar{O}_p$ (Smoke Generator),
3) $\bar{O}_p$ (Lidar) - $\bar{O}_p$ ($\overline{\text{VEO}}$),

are given in Columns 12 through 14, respectively. The average difference between the lidar and smoke generator opacity values (Column 12) ranges from -1 to +9%; between the VEO average and the smoke generator (Column 13), -14 to +11%; and between the lidar and VEO averages (Column 14), -4 to +23%.

For the black smoke opacity range from 6 to 69% (column 6), the overall lidar average opacity is 3% (nearest percent; column 12) higher than that from the smoke generator. The overall average opacity of the VEOs is 2% (column 13) lower than that from the smoke generator. Finally, the overall lidar average opacity is 4% (column 14) higher than the VEOs.

The average opacity values for the lidar (Column 3 of Table VI-7), smoke generator transmissometer (Column 6) and the visible emissions observations (VEOs) (Column 11) are plotted as a function of data run sequence number in Figure VI-16. The data run sequence number is along the abscissa of the plot while opacity is along the ordinate. The individual opacity values are connected with red, blue, and green lines for reading ease, and functional dependence between the plotted points is not implied.

The average opacity values of Columns 3 and 6 of Table VI-7, are plotted against column 11 in Figure VI-17. The red lines connect lidar average opacity values, green lines connect those of the VEOs, and the blue line is the equality line, $\bar{O}_p$ (Lidar), $\bar{O}_p$ ($\overline{\text{VEO}}$) = $\bar{O}_p$ (smoke generator).

The average opacity differences of Columns 12, 13, 14 of Table VI-7 are plotted in Figure VI-18. The average for the red line data is +3% as discussed earlier in this section. The averages for the green and blue line data are -2 and +4%, respectively.

Table VI-7

LIDAR-METHOD 9 COLLABORATIVE TEST
TEST RESULTS FOR BLACK SMOKE

	Nominal	Omega-1 Lidar			TACB Smoke Generators		Visible Emissions Observations				Average Opacity Difference		
Seq. No. (1)	Opacity Value(%), Beginning of Run (2)	Average Opacity(%): $\bar{O}_p$(Lidar) (3)	σ_L(%) (4)	Average Standard Deviation: $\bar{S}_o$(%) (5)	Average Opacity, Smoke Generator: $\bar{O}_p$(Smoke Gen.)(%) (6)	$\sigma_{s.g.}$(%) (7)	Average Opacity(%): $\bar{O}_p$(VEO 1) (8)	Average Opacity(%): $\bar{O}_p$(VEO 2) (9)	Average Opacity(%): $\bar{O}_p$(VEO 3) (10)	Average Opacity of all VEOs(%) (11)	$\bar{O}_p$Lidar- $\bar{O}_p$(Smoke Gen) (%) (12)	$\bar{O}_p(\bar{VEO})$- $\bar{O}_p$(Smoke Gen) (%) (13)	$\bar{O}_p$(Lidar $\bar{O}_p(\bar{VEO})$ (%) (14)
1	5	5	2.56	2.1	6	0.50	5	5	5	5	-1	-1	0
2	10	12	4.87	1.7	11	0.71	7	9	8	8	+1	-3	+4
3	15	16	3.83	1.5	15	0.68	17	17	15	16	+1	+1	0
4	15	19	4.42	1.1	15	0.95	17	16	16	16	+4	+1	+3
5	20	20	4.79	1.4	19	0.93	19	17	18	18	+1	-1	+2
6	25	26	5.26	1.3	26	1.36	21	20	16	19	0	-7	+7
7	25	26	9.43	1.6	25	1.25	28	27	26	27	+1	+2	-1
8	30	30	4.59	1.5	29	0.96	25	25	25	25	+1	-4	+5
9	30	31	8.76	1.4	29	2.70	26	26	26	26	+2	-3	+5
10	35	39	5.85	1.3	36	1.05	23	23	51	33	+3	-3	+6
11	35	36	11.10	1.2	35	0.89	33	29	36	33	+1	-2	+3
12	40	40	5.41	1.3	40	0.84	44	44	44	44	0	+4	-4
13	40	46	6.72	1.5	39	0.80	50	42	46	46	+7	+7	0
14	45	47	4.57	1.4	45	2.02	47	47	46	47	+2	+2	0
15	45	48	12.87	1.7	46	0.96	52	48	52	51	+2	+5	-3
16	50	53	6.12	1.4	50	0.73	32	42	33	36	+3	-14	+17
17	50	59	5.10	1.4	51	1.10	62	64	59	62	+8	+11	-3
18	60	69	5.61	0.7	60	3.97	46	46	46	46	+9	-14	+23
19	70	72	3.08	0.6	67	2.42	52	61	61	58	+5	-9	+14
20	80	72	10.36	0.5	69	12.13	52	63	66	60	+3	-9	+12
										Average:	+3	-2	+4

Notes:

$\bar{O}p$ - Average Opacity

$\bar{S}_o$ - Average standard deviation calculated from the lidar data, Equation (V-15).

σ - Standard deviation calculated from the individual opacity values, O_p.

$\bar{VEO}$ - Average of all VEO opacity readings or values.

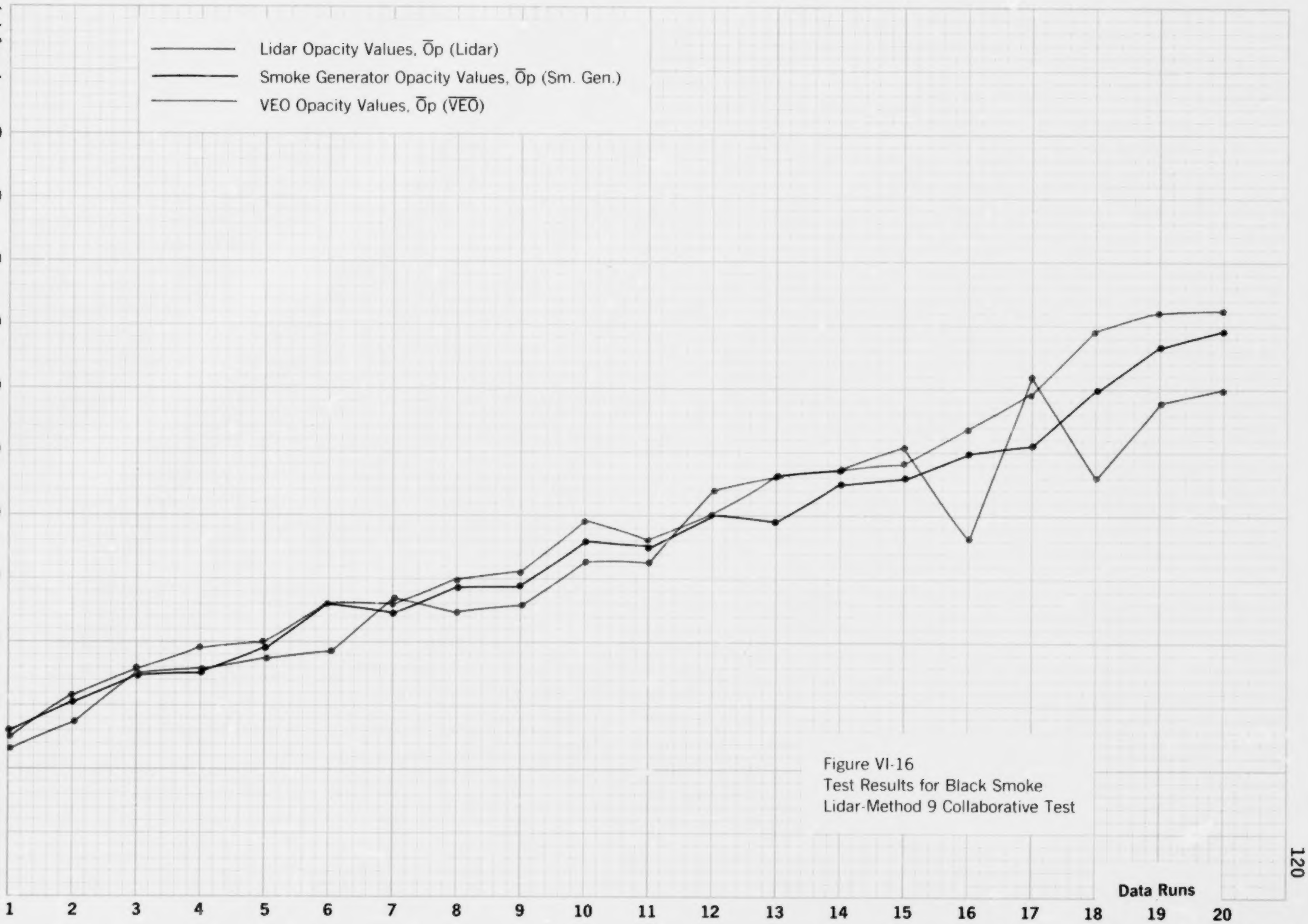


Figure VI-16
Test Results for Black Smoke
Lidar-Method 9 Collaborative Test

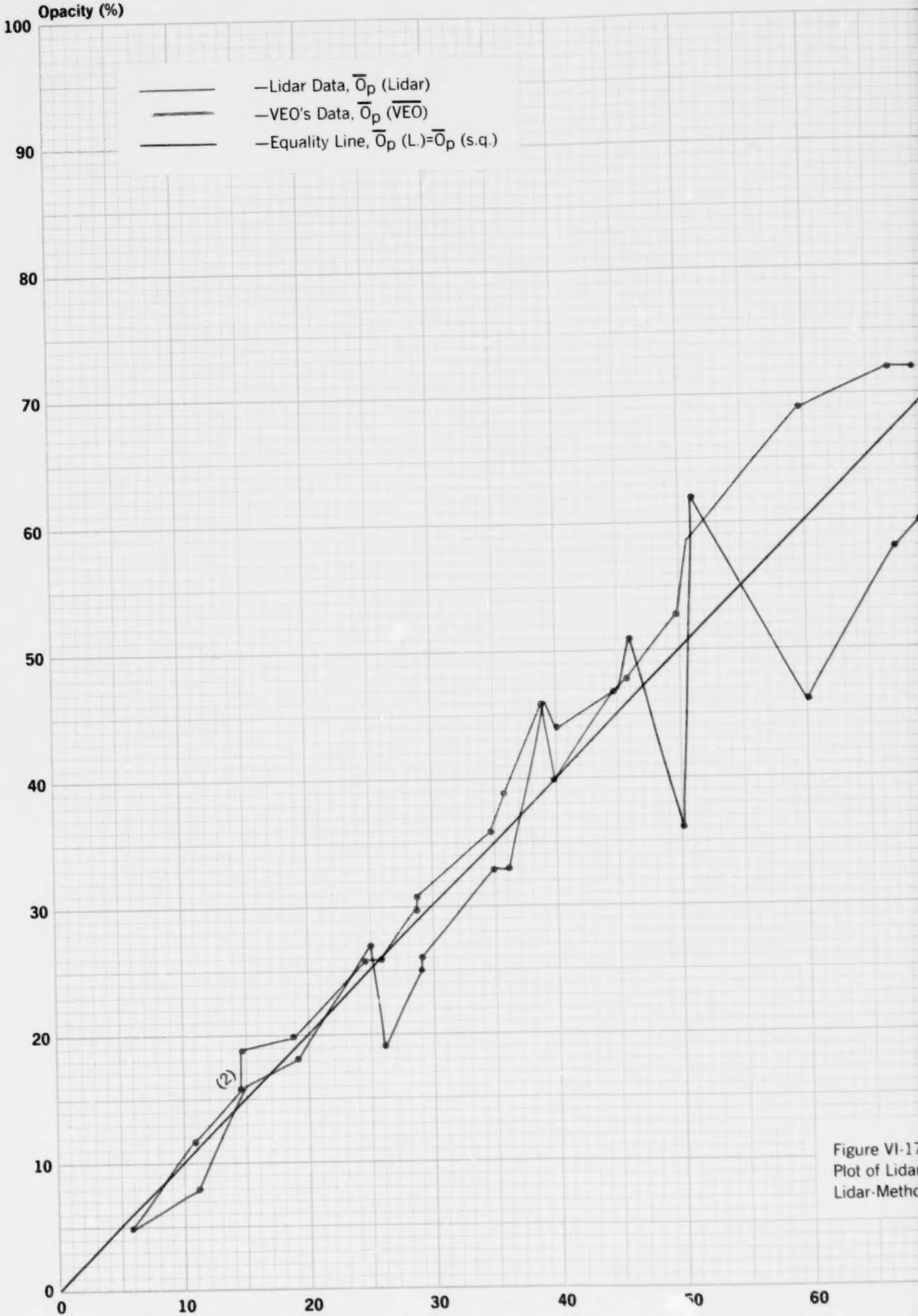


Figure VI-17
Plot of Lidar
Lidar-Metho

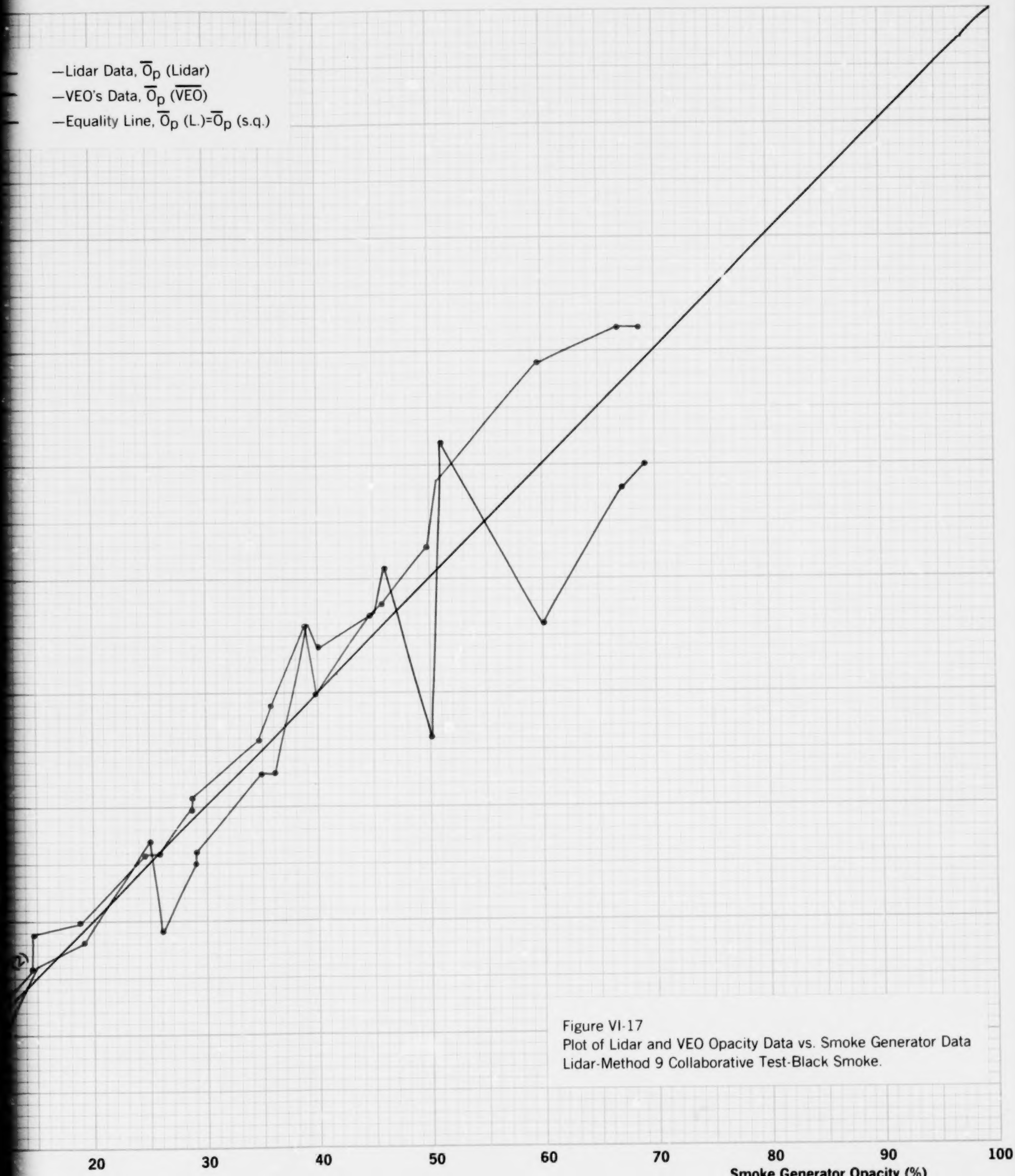


Figure VI-17
Plot of Lidar and VEO Opacity Data vs. Smoke Generator Data
Lidar-Method 9 Collaborative Test-Black Smoke.

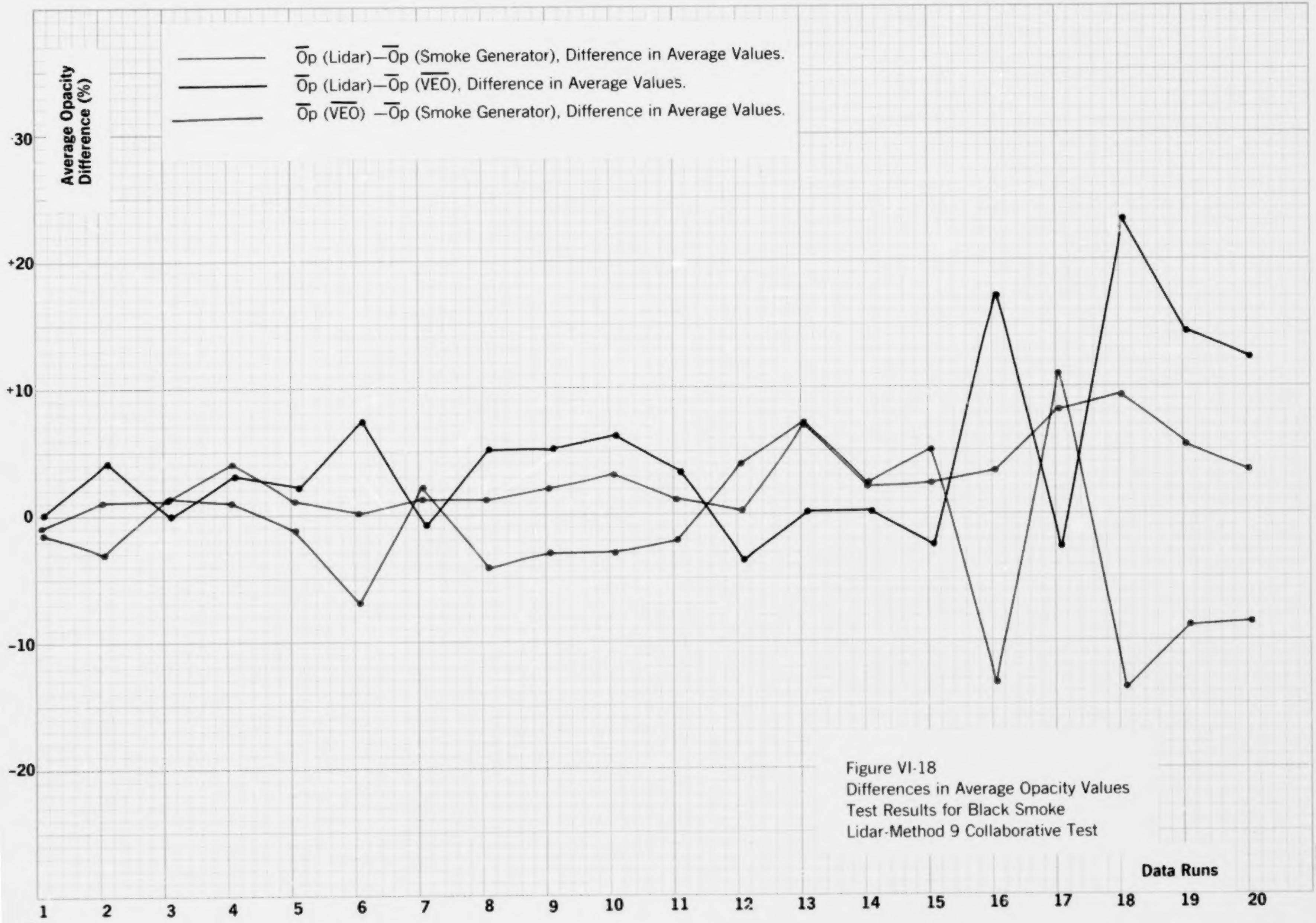


Figure VI-18
Differences in Average Opacity Values
Test Results for Black Smoke
Lidar-Method 9 Collaborative Test

The average values for each respective white smoke data run are recorded in Table VI-8. As discussed for black smoke, the average difference between the lidar and smoke generator opacity values (Column 12) range from -9 to +4%; between the VEO averages and the smoke generator (Column 13), -8 to +16%, and between the lidar and VEO averages (column 14), -23 to +7%. For the white smoke opacity range from 7 to 92% (column 6), the overall lidar average opacity is 4% (nearest percent; column 12) lower than that from the smoke generator. The overall average opacity of the VEOs is 4% (column 13) higher than that from the smoke generator. Finally, the overall lidar average opacity is 8% (column 14) lower than the VEOs.

The average opacity values for the lidar (Column 3 of Table VI-8), smoke generator transmissometer (Column 6), and the VEOs (Column 11) are plotted as a function of data run sequence number in Figure VI-19. The data run sequence number is along the abscissa of the plot while opacity is along the ordinate. The individual opacity values are connected with red blue, and green lines for ease of reading. Functional dependence between the plotted points is not implied.

The average opacity values of Columns 3 and 6 of Table VI-8, are plotted against Column 11 in Figure VI-20. The red lines connect lidar average opacity values, green lines connect those of the VEOs, and the blue line is the equality line, $\bar{O}_p$ (Lidar), $\bar{O}_p$ ($\overline{\mathrm{VEO}}$) = $\bar{O}_p$ (smoke generator).

The average opacity differences of Columns 12, 13, 14 of Table VI-8 are plotted in Figure VI-21. The average for the red line data is -4% as discussed above. The respective averages for the green and blue data lines are +4 and -8%.

Field Use and Crew Training

In order to gain field experience in the use of the lidar, numerous stationary source categories were chosen and the emissions opacity monitored during both day- and nighttime ambient lighting conditions. The source categories monitored to date are the following:

Table VI-8

LIDAR-METHOD 9 COLLABORATIVE TEST
TEST RESULTS FOR WHITE SMOKE

	Nominal	Omega-1 Lidar			TACB Smoke Generators		Visible Emissions Observations				Average Opacity Difference		
Seq. No. (1)	Opacity Value(%), Beginning of Run (2)	Average Opacity(%): $\bar{O}_p$(Lidar) (3)	σ_L(%) (4)	Average Standard Deviation: $\bar{S}_o$(%) (5)	Average Opacity, Smoke Generator: $\bar{O}_p$(Smoke Gen.)(%) (6)	$\sigma_{s.g.}$(%) (7)	Average Opacity(%): $\bar{O}_p$(VEO 1) (8)	Average Opacity(%): $\bar{O}_p$(VEO 2) (9)	Average Opacity(%): $\bar{O}_p$(VEO 3) (10)	Average Opacity of all VEOs(%) (11)	$\bar{O}_p$Lidar- $\bar{O}_p$(Smoke Gen) (%) (12)	$\bar{O}_p$($\overline{\text{VEO}}$)- $\bar{O}_p$(Smoke Gen) (%) (13)	$\bar{O}_p$(Lidar $\bar{O}_p$($\overline{\text{VEO}}$ (%) (14)
1	5	5	2.08	1.7	7	0.60	5	6	5	5	-2	-2	0
2	10	6	4.31	1.7	10	0.87	16	15	17	16	-4	+6	-10
3	15	12	3.79	1.7	17	0.91	15	13	15	14	-5	-3	-2
4	20	19	4.71	1.6	19	2.09	26	24	22	24	0	+5	-5
5	25	21	5.24	1.5	25	1.35	40	43	33	39	-4	+14	-18
6	30	23	7.06	1.7	32	2.67	41	51	45	46	-9	+14	-23
7	35	32	6.43	1.2	36	1.49	53	49	53	52	-4	+16	-20
8	40	37	5.25	1.2	42	2.69	45	41	40	42	-5	0	-5
9	45	35	5.82	1.2	43	1.69	44	35	54	44	-8	+1	-9
10	50	46	10.04	1.1	50	0.93	56	59	54	56	-4	+6	-10
11	60	59	8.43	0.7	62	2.17	71	70	69	70	-3	+8	-11
12	70	69	4.04	0.6	71	2.02	76	75	77	76	-2	+5	-7
13	80	74	2.43	0.5	79	1.75	69	79	66	71	-5	-8	+3
14	90	96	8.43	0.1	92	0.97	95	83	90	89	+4	-3	+7
										Average:	-4	+4	-8

Notes:

$\bar{O}p$ - Average Opacity

$\bar{S}_o$ - Average standard deviation calculated from the lidar data, Equation (V-15).

σ - Standard deviation calculated from the individual opacity values, O_p.

$\overline{\text{VEO}}$ - Average of all VEO opacity readings or values.

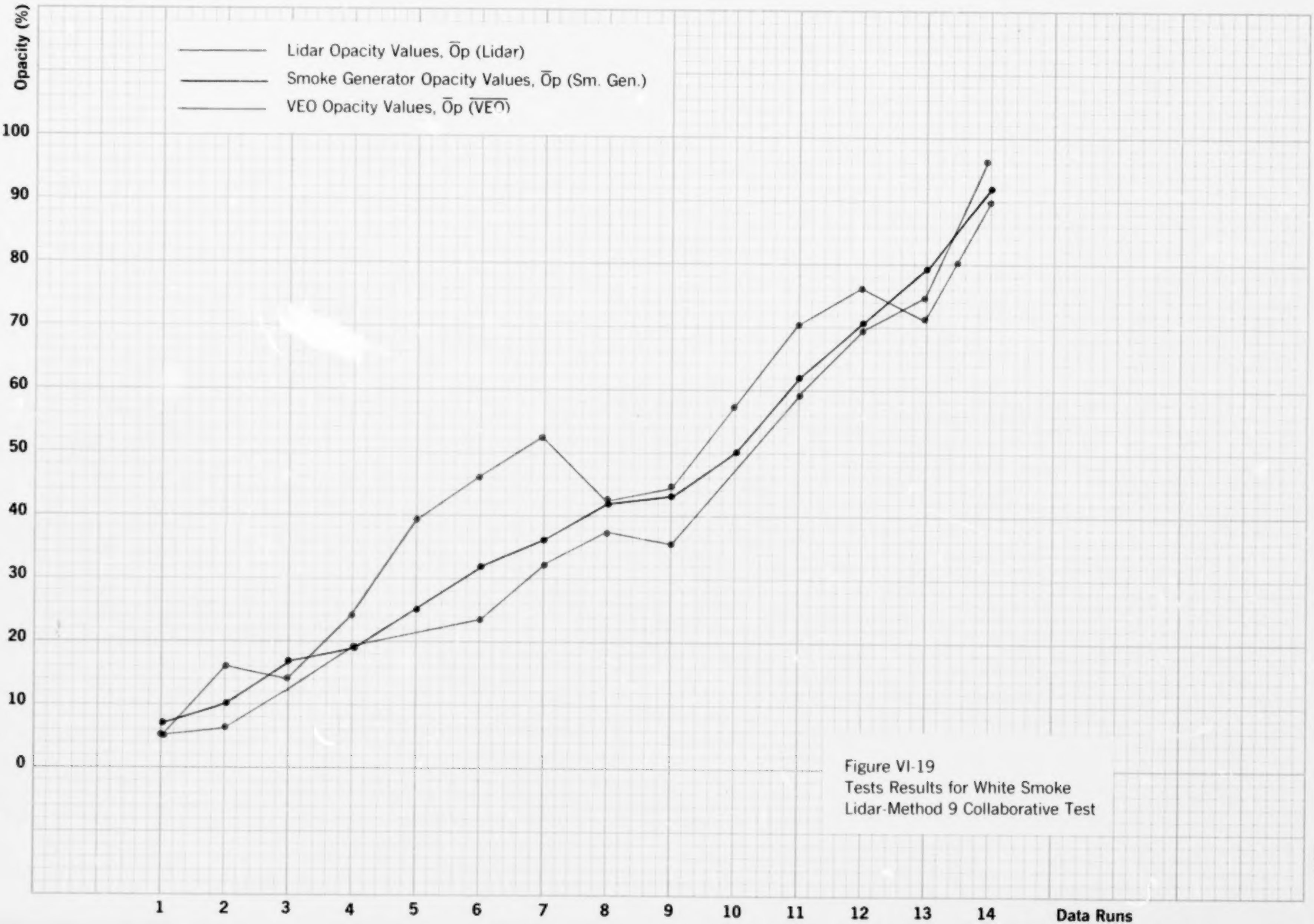


Figure VI-19
Tests Results for White Smoke
Lidar-Method 9 Collaborative Test

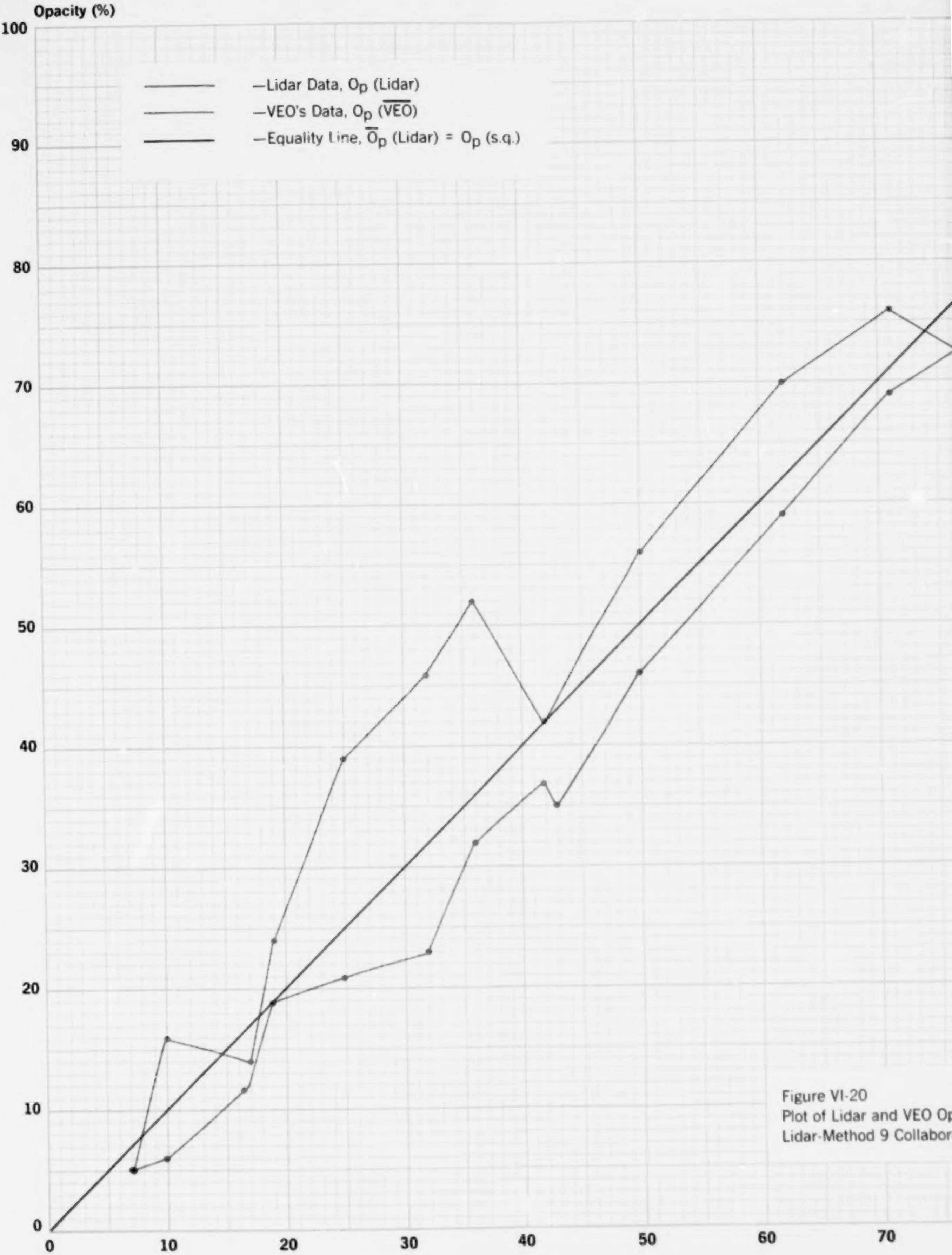


Figure VI-20
Plot of Lidar and VEO Op
Lidar-Method 9 Collabor

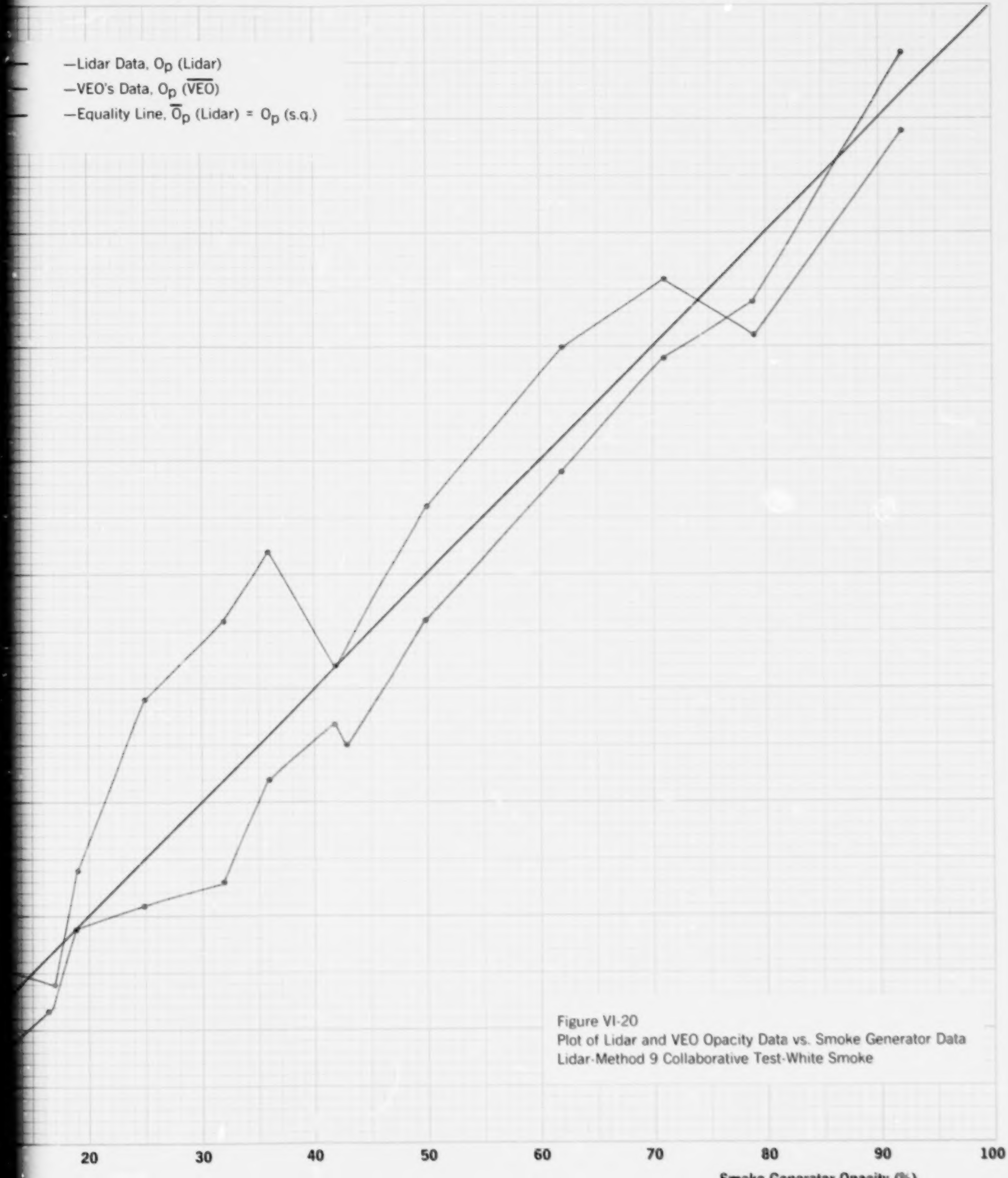


Figure VI-20
Plot of Lidar and VEO Opacity Data vs. Smoke Generator Data
Lidar-Method 9 Collaborative Test-White Smoke

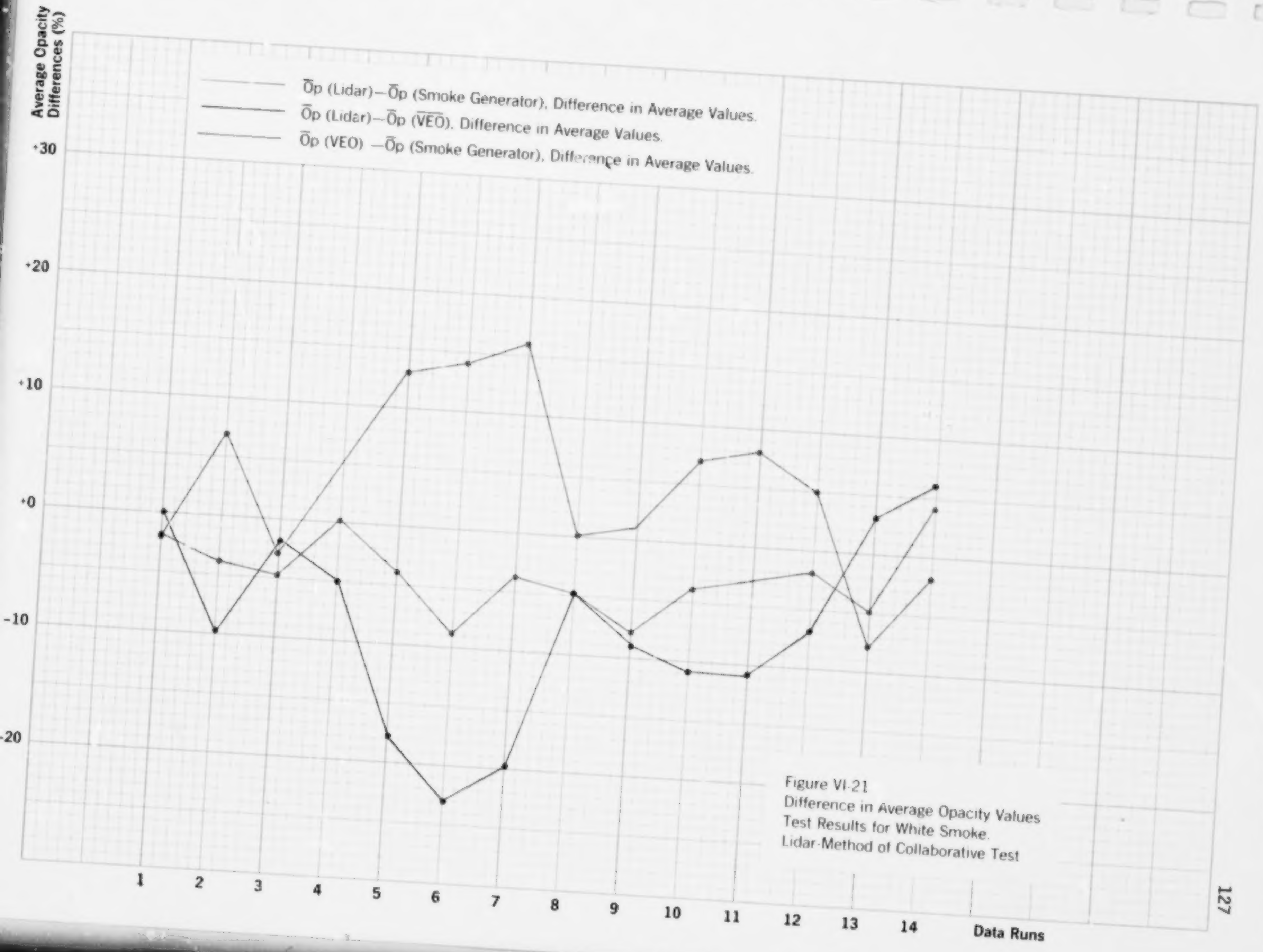


Figure VI-21
Difference in Average Opacity Values
Test Results for White Smoke.
Lidar-Method of Collaborative Test

- Petroleum refineries
- Glass manufacturing plant
- Steel plant (roof monitors and bag houses)
- Power plants (coal and oil-fired)
- Lead smelter
- Copper smelter
- Zinc smelter
- Acid plant
- Detergent manufacturing plant
- Cement manufacturing plant
- Plastics manufacturing plant
- Chemical plants (pesticides, herbicides, etc.)
- Petrochemical plants
- Incinerators

These source investigations provided field operating experience to the lidar operators under widely varied meteorological (clean air to light rain) and lighting (clear, cloudy, darkness, etc.) conditions. Numerous plume categories have been monitored which include attached steam plumes, detailed steam plumes, white, black, gray and rust-colored plumes.

In summary, the operational experiences gained by the operations crews using the lidar in the field was most valuable. The Omega-1 Lidar is easily employed in the field as an accurate opacity measurement tool during both day- and nighttime hours.

VII. LIDAR SAFETY IN THE ENVIRONMENT

Safety for the lidar operators and the public is the first and foremost consideration in the operation of the Omega-1 Lidar. This lidar was designed with the highest practical laser safety standards incorporated.[43-47] It requires two operators or crew members for normal operation. One operator, the lead operator, is at his duty station in the computer room [Section V] monitoring the performance of the entire lidar system. The second operator, the lidar observer, is at his duty station in the laser room at all times while the lidar is in operation. His function is primarily to aim the laser transmitter/receiver into the smoke plume under investigation and continuously observe the local environment which contains the laser's beam.

Each prospective lidar operator is trained in the EPA-NEIC Lidar (laser) Safety Program. This training program consists of about 50 hours of classroom, laboratory, and field instruction which is specifically geared to the use of high-power lasers in the atmosphere. A written final examination is given to each prospective lidar operator. The required training for the lead operator (one of the two operators) takes about 200 hours additional field instruction.

Each certified lidar operator is provided with extensive training in the following areas:

- Basic Geometric Optics
- Optical Reflectance, Transmittance, and Absorption (Attenuation)
- Laser Fundamentals [Class 1 and Class 4 lasers (power rating)]
- Laser Beam Characteristics (temporal and spatial)
- Laser Hazard Analysis (eyes and skin)
- Standards and Compliance Documents
- Determination of Laser Hazards

- Compliance/Control Measures
- NEIC Lidar (Laser) Safety Program
- Calculation of Meteorological Visual Range from Lidar Data [Appendix B(e)]
- Calculation of Lidar Eyesafe Distance [Appendix B(e)]
- Calculation of Parameters for FAA Report [Appendix B(f)]

This training not only covers the optical aspects of laser safety, but also the operations in and around the high-voltage power supplies for the laser cavity and the Q-switch.

When each prospective lidar operator has satisfactorily completed the Lidar Safety Program, this person is certified as a lidar operator and issued a certificate of competence. The lead operator has an additional certification which documents his/her competence to operate the overall lidar system safely.

The lidar operators are trained in the following lidar safety procedures:

a. The lead operator is responsible for the overall safe operation and maintenance of the Omega-1 lidar under both field and laboratory (test) conditions. When unsafe conditions exist, it is the lead operator's responsibility to ensure that the lidar is not operated. He shall suspend, restrict, or terminate the operation of the Lidar's Class 4 laser system if, in his judgment, proper operating conditions do not exist.

b. Each lidar operator is required to exercise sound judgment and common sense in the operation and maintenance of the lidar at all times. The laser shall not be operated in a potentially dangerous environment until the necessary safety precautions have been carried out. The laser shall not be operated with the electromechanical (safeguard) shutter inhibited or removed, in visible emissions source data gathering.

c. Any equipment changes/modification or alteration that would in any way affect the safe operation and maintenance of the lidar shall be recorded in the Omega-1 Lidar Maintenance Log Book. All lidar operators shall be notified of such before they subsequently work within the lidar.

d. The lidar operator shall not operate the laser during diagnostic tests, or at any other time, with the doors/panels removed from the main power supply without first installing the safeguards required for operator's protection and the safety of the equipment.

e. Only the lidar operators are permitted in the laser room when the laser is either on standby or in operation.

f. The lead operator is responsible for directly coordinating all operational plans near airports with the applicable officials of the Federal Aviation Administration (FAA) prior to operation. He shall also calculate and provide them: the approximate eye-safe distance or range from the lidar, geographic location of the lidar within the applicable urban area, direction of proposed operation, and operating times. Where available, the lead operator shall also provide the FAA with the laser beam path information as a function of the altitude intervals [500 ft (as required), 1,000-ft intervals above ground level] with respect to the appropriate navigational radials transmitted from the nearest VOR (VHF omni range broadcasting station).

g. No lidar operator is permitted to take dulling drugs/medicines and/or alcoholic beverages 8 hours prior to or during the operation of the lidar.

h. Everyone at NEIC who works in the lidar is responsible for keeping the entire lidar system, truck, etc., hazard-free through appropriate operation and maintenance.

The parameters listed in Item f are obtained at the lidar test site. The atmospheric extinction (laser beam attenuation) along the lidar's line-of-sight is measured from a lidar signal through clear air, and the meteorological visual range (R_{mvr}) is calculated using the extinction coefficient obtained through this process. The extinction effect of the smoke plume under investigation is also calculated. The two resultant factors are combined and the approximate eye-safe distance (direct-beam viewing) is calculated. This parameter, along with the other parameters, is plotted on a flight (sectional) map. The elevation angle of the lidar's line-of-sight is obtained from the laser pedestal by the lidar computer along with the direction (magnetic compass reference) of operation. The intersection of the lidar's line-of-sight with the predominant flight levels or altitudes is calculated with reference to the above mentioned VOR. These data are then immediately telephoned (via radio telephone) to the appropriate supervisor at the local FAA facility.

This procedure has been used in past lidar operations and has been effective. The FAA personnel in large metropolitan areas, with whom the lidar personnel have worked in past investigations, have been well pleased with the detail of information given them.

The basic rules concerning the safe operation of the lidar are:

a. The Omega-1 Lidar shall be operated only when conditions are conducive to safe operation for both the lidar crew and the public in the immediate environs of the lidar. The laser shall not be fired if people, aircraft, etc. are visible within, or anywhere near, the field-of-view of the aiming telescope [Figure V-1]. The field-of-view of this small telescope is 1,135 times greater than the beam width of the laser pulses. The large 8-inch receiver telescope can also be used for a greatly magnified view along the lidar's line-of-sight.

b. All electrical, electronic, and optical equipment within the lidar shall be maintained in a safe operating condition. Preventive maintenance/inspections shall be performed on the laser including the optical and electro-mechanical components within the invar optical rails, the main power supply, and the Q Switch (Pockels Cell) power supply once a week while in use and as otherwise required. Proper operation of all interlocks and other electrical safety devices will be verified at those times.

c. When the lidar is operated in the interrogation of a visible emissions source or for any other purpose, the designated lidar crew member (lidar safety observer) is required to be in the laser room serving as safety observer. This person shall continually observe the area or direction into which the laser beam is being discharged. This person shall be in direct communication with the other lidar crew member located in the computer room via the lidar intercommunications system. This observer shall have in his hands the laser "inhibit switch" which, when activated, prevents laser operation. The observer will actuate the "inhibit switch" if personnel, aircraft, etc., come into or anywhere near the field-of-view of the aiming telescope. In an area where people, aircraft, etc. (Item a), are periodically anywhere near the field-of-view (fov) of the aiming telescope, the laser shall be operated from the safety observer's duty station with the remote "fire-switch" which is located adjacent to the aiming telescope. (The fire-switch is a guarded push button switch placed out of the way of personnel traffic/motion so as to prevent inadvertent firing of the laser.)

d. When the laser is not in operation, such as during "stand-by" times, the laser's safety shutter shall be closed. The switch that controls the optical shutter is located on the laser's main control panel in the computer room.

e. Whenever the high voltage power supplies of the laser are subject to maintenance and diagnostic tests, two lidar crew members shall be present to preclude any possibility of carelessness, such as the improper use of tools, when the system is energized and high voltage is present.

The technical aspects of the safe operation and maintenance of the Omega-1 Lidar are too many and too detailed to give here. They are followed carefully to assure the safety and well-being of the lidar crews and the public.

The detailed laser safety program, fully implemented at EPA-NEIC for the lidar, has been designed and put into practice based, in part, upon the following references:

a. American National Standard for the Safe Use of Lasers, ANSI Z 136.1-176, 8 March 1976.

b. U.S. Army Technical Manual TB MED 279, Control of Hazards to Health from Laser Radiation, February 1969.

c. Laser Institute of America Laser Safety Manual, 4th Ed.

d. U.S. Department of Health, Education and Welfare, Regulations for the Administration and Enforcement of the Radiation Control for Health and Safety Act of 1968, January 1976.

e. Laser Safety Handbook, Alex Mallow, Leon Chabot, Van Nostrand Reinhold Co., 1978.

Two additional references regarding the use of laser products [48,49] are the following Federal Register rules:

a) Federal Register, Volume 40, Number 148, Thursday, July 31, 1975, Performance Standard for Laser Products, Food and Drug Administration, U.S. Dept. of Health, Education, and Welfare.

b) Federal Register, Volume 43, Number 229, Tuesday, November 28, 1978. Amendment to Performance Standard for Laser Products, Food and Drug Administration, U.S. Dept. of Health, Education, and Welfare.

VIII. USE OF THE OMEGA-1 LIDAR IN EPA ENFORCEMENT

The EPA-NEIC Omega-1 lidar will be used extensively to make opacity measurements on visible emissions from stationary sources for enforcement purposes. It is an effective remote sensing tool for accurately measuring plume opacity during both day and night (lidar contains a pulsed laser as its own light source) lighting conditions with significantly greater accuracy than obtained with Reference Method 9. Measurements will be made of the optical opacity of particulate emissions from large and small diameter stacks alike [Section V].

Lidar is not affected by background conditions such as clear sky, cloudy sky, hills in the background, nor the angle of the sun with respect to the lidar (the lidar receiver, although solar blind, should not look directly into the sun). Lidar does not consider plume/background contrast in the measurement of opacity. In contrast, negative errors can be made when visible emissions observers (Reference Method 9) view a plume under less-than-ideal background-to-plume color/luminescent contrast conditions. On a hazy or a cloudy day with a white or gray plume the reference method displays this negative error (bias) due to the lower contrast between the light-colored plume and the light-colored (hazy or cloudy) background.

Lidar is not time- or endurance-limited as are visible emissions observers. Being mechanical in nature, lidar can make discrete opacity measurements with a pulse repetition rate as fast as 1 measurement every two to three seconds, over a continuous data run or sequence from a few seconds to as long as several hours. Lidar maintains consistent measurement accuracy over long testing periods where the observers tire, influencing their ability to determine opacity with consistent accuracy. Even though teams of visible emissions observers may make observations in shifts, the opacity-determination accuracy from observer to observer is not constant.

As discussed in Section VI of this report, the Omega-1 Lidar was thoroughly calibrated with the optical generator (internal calibration mechanism). The lidar was also subjected to tests with a smoke generator that is used to certify visible emisssions observers in accordance with the requirements of Reference Method 9. The analyzed opacity data showed that the lidar opacity values ranged from 0% average difference to -3% (lower), with respect to the smoke generator transmissometer, for 83% of the 23 data runs. For the complete set of data runs, all of the lidar average opacity values ranged from 0% to 6% lower.

A screen target test (Section VI) was conducted using four metallic screens to simulate constant plume opacity. Their respective opacity values ranged from 30.9 to 75.8%. The average difference between the lidar-measured opacity values for each screen and the laboratory-measured value for each screen ranged from -1.1% (lower) to 1.5% (higher). This test clearly shows that lidar measures opacity with consistent accuracy and non-subjectivity. The results of this test also demonstrate that lidar measures opacity precisely. The absolute precision ranged in value from 0.4% to 1.1%.

A collaborative test (Section VI) was conducted using the Omega-1 Lidar, two teams of three visible emissions observers, and a smoke generator for a source of black and white smoke plumes. The analyzed opacity data from these three sources showed that the mean of the average difference in opacity values for the lidar with respect to the visible emissions observations (VEOs) was +4% for the black smoke (mean of the average difference values in column 14 of Table VI-7), and -8% for white smoke (column 14 of Table VI-8). For black smoke, the lidar-measured plume opacity values were higher than the VEOs for 60% of the data runs with the overall mean of the average difference values being +4%. For white smoke, the lidar opacity values were higher than the VEOs for only 14% of the data runs with the overall mean of the average-difference values being -8%. For 40% of the data runs, lidar measured the plume opacity low with respect to VEOs for black smoke. In 86% of the white smoke data runs, lidar measured plume opacity lower than the VEOs. This test shows that the lidar mechanism will neither always determine opacity higher nor always lower than the VEOs.

As a result of the collaborative test discussed above and the collaborative tests between opacity and mass emissions (Section III), a definition of correlation between opacity determined with Reference Method 9 and opacity measured by lidar (Alternate Method 1) was developed. It states that 0% opacity by Reference Method 9 is defined as being less than or equal to 5% opacity by lidar measurement. Opacity values calculated from lidar data shall be lowered by 5% to insure consistency with Reference Method 9. If lidar opacity values obtained by Alternate Method 1 indicate noncompliance with opacity standards or regulations, so will Reference Method 9.

The promulgation of the lidar mechanism as Alternate Method 1 to Reference Method 9 is only a change of measurement technique for plume opacity and does not change the New Source Performance Standards (NSPS) or state/local regulations. Reference Method 9 is limited by the human instrument; the lidar mechanism does not have these restrictions. For example, the opacity reading temporal cycle for Reference Method 9 is 1 reading/15 seconds for 6 minutes for a total of 25 readings. The lidar mechanism can easily determine opacity values for duration intervals from a few minutes to as long as 5 hours. The lidar measures opacity at a nominal pulse repetition frequency or firing rate of 1 pulse every 10 seconds or 6 pulses/min. For highly variable smoke plumes and meteorological conditions, the firing rate is usually increased from 1 pulse every 10 seconds to 1 pulse about every 4 to 5 seconds. The lidar's performance integrity is the same in either case. The human observer would easily tire under these conditions, possibly having a significant impact on his ability to read smoke plume opacity with consistent accuracy.

The lidar mechanism is as easily applied to opacity measurement of intermittent and cyclic visible emissions as it is to continuous sources. However, these noncontinuous emissions are monitored for at least three cycles or occurrences to adequately determine compliance/noncompliance with a particular opacity regulation or standard.

The remainder of this section is devoted to the further delineation of the use of lidar in the enforcement program of the Agency. Lidar position and plume monitoring requirements are discussed first followed by lidar opacity data reduction, correction, and reporting requirements.

Lidar Position: The lidar is placed in position at a distance from the source sufficient to provide an unobstructed view of the source emissions or plume. The source must be at a range of at least 50 meters, preferably 100 meters, greater than the lidar's transmitter/receiver convergence distance [Figure IV-3] along the line-of-sight or field-of-view. The maximum effective opacity measurement distance of the lidar is a function of local atmospheric conditions, plume diameter, and laser beam diameter. The test position or location of the lidar is selected so that the diameter of the laser beam at the measurement point within the plume is no larger than three-fourths the plume diameter. The beam diameter is calculated by

$$D(\text{Lidar}) = A + R\phi \leq 0.75\ D(\text{plume}), \qquad \text{(VIII-1)}$$

where:

D(plume)	is the diameter of the plume
ϕ	is the divergence of the laser beam measured in radians
R	is the range from the lidar to the source exit
A	is the exit diameter of the laser beam
D(lidar)	is the diameter of the laser beam at range R.

The lidar range is obtained by aiming and firing the laser at the emissions source structure (stack exit, for example) immediately below the outlet. The range value is obtained using the leading edge of the source's signal spike within the lidar's optical backcatter signal.

When there is more than one source of emissions in the immediate vicinity of the plume being tested, the lidar is positioned so that the laser beam passes through only a single plume, free from any interference of the other plumes for a minimum of 50 meters (determined from the backscatter signals) in each region before and behind the plume along the line-of-sight. The lidar is initially positioned so that its line-of-sight is approximately perpendicular to the plume.

When measuring the opacity of emissions from rectangular outlets (e.g., room monitors, open baghouses, noncircular stacks, etc.), the lidar is placed in a position so that the line-of-sight is approximately perpendicular to the longer (major) axis of the outlet.

Lidar Operational Restrictions: The lidar receiver is solar blind. However, as stated in Section V, it should not be aimed directly into the sun. To insure the integrity of the lidar A-scope data (low background optical noise), the lidar receiver should not be aimed to within an angle of ± 15° (cone angle) of the sun.

The lidar should not be used to make opacity measurements during times of heavy thunderstorms, moderate-to-heavy snow storms, hail storms, high-wind storms, high-fugitive dust levels, and fog conditions at or near the ground in the vicinity of the lidar or the stationary source being investigated. These meteorological conditions give rise to highly variable reference and plume data signals making the associated standard deviation values, S_0, larger.

The Omega-1 Lidar is usually not used to measure the opacity of emissions from coke batteries due to possible laser safety hazards that might exist with workers on top of the coke battery.

With one exception, whenever the lidar is not aimed into the most dense region of a particulate plume, the opacity value measured by lidar will be lower than the value obtained at the most dense region. The partial missing of the plume with the laser beam is improper operation of the lidar and not an operational variation in procedures or technique. The exception deals with the laser beam's central intense spot partially incident upon the structure of the stationary source's outlet. If A_0 is the cross-sectional area of the laser beam at the range of the stack, then the opacity value, O_p', calculated with the laser beam partially striking the exit structure of the stack, is related to the true opacity value, O_p, by

$$O_p' = \frac{O_p}{A_p} \quad , \; A_p \leq 1 = A_0 \quad ,$$

where:

A_p = the fraction of the laser beam's cross-sectional area that is not incident upon the stack structure, i.e., that portion that passes on through the plume.

In the limit, as complete blockage of the laser beam occurs,

$$O_p' = \lim_{A_p \to 0} \frac{O_p}{A_p} = 100\% \text{ opacity}$$

Therefore, the lidar operators must insure and verify that the laser beam is aimed through the most dense region of the plume clearly above the stack exit structure. In the field it is easy to determine visually if the central intense spot of the laser beam is partially or completely incident upon the exit structure of the stack.

Reference Signal Requirements: Once placed in its proper position for the measurement of plume opacity, the laser is then aimed and fired with the laser beam or lidar line-of-sight located near the outlet height of the stationary source and rotated horizontally, usually up-wind, to a position clear of the source structure and the associated plume. The backscatter signal obtained from this aiming position is the ambient-air or reference signal. The lidar lead operator inspects this signal [Section V] on the oscilloscope display to: (1) determine if the lidar line-of-sight is free from interference from other plumes and from physical obstructions such as cables, power lines, etc., for a minimum of 50 meters in each region (near and far) before and behind the plume, and (2) obtain a qualitative measure of the homogeneity of the ambient air by observing any signal spikes on the backscatter signal.

Should there be any signal spikes on the reference signal within a minimum of 50 meters in each region before and beyond the plume, the laser is then fired three more times and the operator inspects each reference signal on the oscilloscope display. If the spike(s) remains, the azimuth angle of the lidar line-of-sight is changed and the above procedure is repeated. If the spike(s) disappears in all three backscatter signals, the lidar line-of-sight is acceptable when there is shot-to-shot consistency and there is no interference from other plumes.

Conditions may occur where the lidar mechanism cannot be effectively used to make opacity determinations. During times of heavy thunderstorms, moderate-to-heavy snow storms, hail storms, high-wind storms, high-fugitive dust, and fog conditions at or near the ground in the vicintity of the lidar or the stationary source under investigaion, opacity measurements cannot effectively be made. This is because there is no shot-to-shot consistency in a series of reference measurements obtained during these highly varied conditions. A good quality reference shot, $1/R^2$ corrected, is shown in Figure VI-10. Ambient meteorological conditions as those described above give rise to lidar backscatter signal quality that is less than that shown in the near region (to the left of the plume spike) of Figure V-14(c), where there would be no Area 1 of Area 2. Under these conditions, an opacity measurement cannot be made, and the lidar operators would have to wait for improved atmospheric conditions. If there is no shot-to-shot consistency in a series of reference measurements obtained over a time span of 20 seconds, and if there are no flat areas such as Areas 1 of 2 in Figure V-14(c), then lidar opacity determinations cannot be made. This applies to both day and nighttime lighting conditions.

However, the Omega-1 Lidar has been effectively used to measure plume opacity during conditions of steady light-to-moderate rain with no wind gusts, i.e., no thunderstorm condtions. In this case, good qualty shot-to-shot reference measurements were obtained because the rain was evenly distributed throughout the local area.

Shot-to-shot consistency of a series of reference measurement signals over a period of 20 seconds is easily verified. With the PMT detector gain (high voltage level) and the digitizer input voltage level adjusted so that the backscatter signal convergence peak (not corrected for the $1/R^2$ effect) is at or very near the top of the oscilloscope display [Figure VI-9], or the flat signal (corrected for the $1/R^2$ effect) is adjusted by both of the above voltage parameters so that the flat signal level is about 5 cm above the bottom of the vertical display grid [Figure VI-10], the consistency is verified in either of two ways: (1) the lidar operator observes the backscatter signal amplitude variations from shot-to-shot on the oscilloscope display. If the selected near-region (signal) pick interval amplitude on the display were observed to be about 4.8 cm on the vertical grid above the zero signal level for a given reference measurement (about 155 digital counts on a scale from 0 to 255 counts - the output limits of the digitizer), then the subsequent reference signals the selected far-region pick interval amplitude should vary no more than ± 0.3 cm (± 9 counts) from that of the near-region amplitude. (2) With one of the first few reference signals accepted into the lidar computer as a reference measurement, and the subsequent reference measurements in the short series treated as though they were plume data signals, the computer would calculate the opacity, Equation (V-4), for each of the subsequent signals or shots. For reasonable shot-to-shot consistency, the opacity values shall be within ±3% of 0% opacity and the associated S_0 values less than or equal to 8% (full scale).

Three reference signals are obtained and recorded within a 90-second time period prior to beginning a data run. Another set of three reference signals is obtained and recorded within 3 minutes of completion of the same data run.

If a set of reference signals fails to meet the requirements given above, then all plume data signals recorded from the last set of acceptable reference signals to the failed set, are discarded.

During the subsequent analysis of the lidar data, the reference and data measurement signals are analyzed in the same sequence or order that they were recorded in the field.

Temporal Criterion for Additional Reference Signals: An additional set of three reference measurement signals is obtained during a data run if there is a change in wind direction or plume drift of 30° or more from the direction that was prevalent when the last set of reference signals was recorded. Also, an additional set of reference signals is obtained if there is a change in amplitude in either the near region or the far region (not due to change in plume opacity) of the plume data signal that is greater than ±0.3 cm (vertical displacement on the oscilloscope display) from the near region amplitude of the previous signal, and this change remains for 30 seconds or more.

Plume Data Signal Requirements: The laser is aimed at the region of the plume (dry, nonhydrated) which displays the greatest opacity. The lidar operator must visually verify that the laser is aimed clearly above the source's exit structure, discussed previously.

Once properly aimed, the lidar is placed in operation with a nominal pulse or firing rate of six pulses/min (1 pulse/10 sec). The lidar operator observes the plume data (backscatter) signals on the oscilloscope display to determine the need for additional reference signals, as discussed above. The plume signals are recorded from lidar start to stop and are called a data run. The length of a data run is determined by operator discretion. Short-term stops of the lidar to record additional reference signals do not constitute the end of a data run if plume signals are resumed within 90 seconds after the reference signals have been recorded, and the total stop or interrupt time does not exceed 3 minutes.

Steam (Hydrated) Plumes: The lidar will be used to measure the opacity of hydrated or so-called steam plumes. (To the extent practicable, the lidar operators will have technical information with them regarding the respective process and the control equipment for each stationary source to be listed. This information is usually supplied by the respective EPA or state offices requesting the studies.) As listed in the reference method, there are two types: attached and detached steam plumes.

Attached Steam Plumes: When condensed water vapor is present within a plume as it emerges from the emission outlet, the opacity measurements shall be made with the lidar at a point within the residual plume where the condensed water vapor is no longer visible.

During daylight hours the lidar operator can usually locate the most dense portion of the residual plume visually. The operator can then aim the lidar transmitter/receiver into that portion or region of the plume. During either day- or nighttime operations the lidar is used to locate the most dense region of the residual plume, i.e., the region of highest opacity. (A high intensity spotlight is available within the Omega-1 Lidar to aid the lidar operator in aiming the transmitter/receiver at night.) The lidar operator scans the transmitter/receiver (lidar measuring opacity) along the longitudinal axis or center line of the plume from the emissions outlet to a point just beyond the steam plume. The steam plume will have nearly 100% opacity while the residual plume opacity is probably lower. If the residual plume also has a 95 to 100% opacity, then the lidar operator may also have to observe color differences as an added assurance that the lidar is aimed completely within the residual plume. Plume reflectivity can also be used to accomplish this same task. The steam plume is white and highly reflective while the residual plume will be lower in reflectivity. If the lidar operator does not obtain a clear indication of the location of the residual plume, opacity data is not recorded.

Once the residual region of the plume is located (along its center line), the lidar transmitter/receiver is scanned perpendicular, as practicable, to this axis in order to locate the region of highest opacity. Opacity is measured at this location within the plume. Aiming adjustments are made to the lidar line-of-sight within the residual plume to correct for the following: movement of the region of highest opacity out of the lidar line-of-sight (away from the laser beam) for more than 15 seconds, expansion of the steam plume (air temperature lowers and/or relative humidity increases) so that it just begins to encroach on the field of view of the aiming telescope, or a decrease in the size of the steam plume (air temperature higher and/or relative humidity decreases) so that regions within the residual plume whose opacity is higher than the one being monitored, are present.

The distance from the stack to the position within the plume where these opacity measurements are collected is readily obtained by a calculation using the lidar range to the stack, the lidar range to the plume measurement position, and the azimuth/elevation angles between the stack and the plume monitoring position. The geometry for the calculation is depicted in Figure VIII-1. The point P_s $(R_s, 0, \beta_s)$ is at the stack emissions outlet, and P_p (R_p, ψ, β_p) is the coordinate of the lidar measurement position within the plume. These points are described in spherical coordinates. The parameter R_s is the range from the lidar to the stack outlet; R_p is the range from the lidar to the plume measurement position or point. The angle β_s is the elevation angle of the lidar line-of-sight above the horizontal plane to the stack outlet, and β_p is the elevation angle of the lidar line-of-sight above the horizontal plane to the plume measurement point. The angle ψ is the azimuthal angle, in the horizontal (xy) plane, of the lidar line-of-sight measured from the y-axis which contains the lidar and stack outlet. The parameters R_s, R_p, β_s, β_p, and ψ are measured with the lidar.

The distance from point P_s to P_p is $R_{\delta\psi}$. In rectangular coordinates $R_{\delta\psi}$ is given as

$$R_{\delta\psi} = \quad P_p - P_s \quad = [(x_p - x_s)^2 + (y_p - y_s)^2 + (z_p - z_s)^2]^{\frac{1}{2}} \qquad \text{(VIII-2)}$$

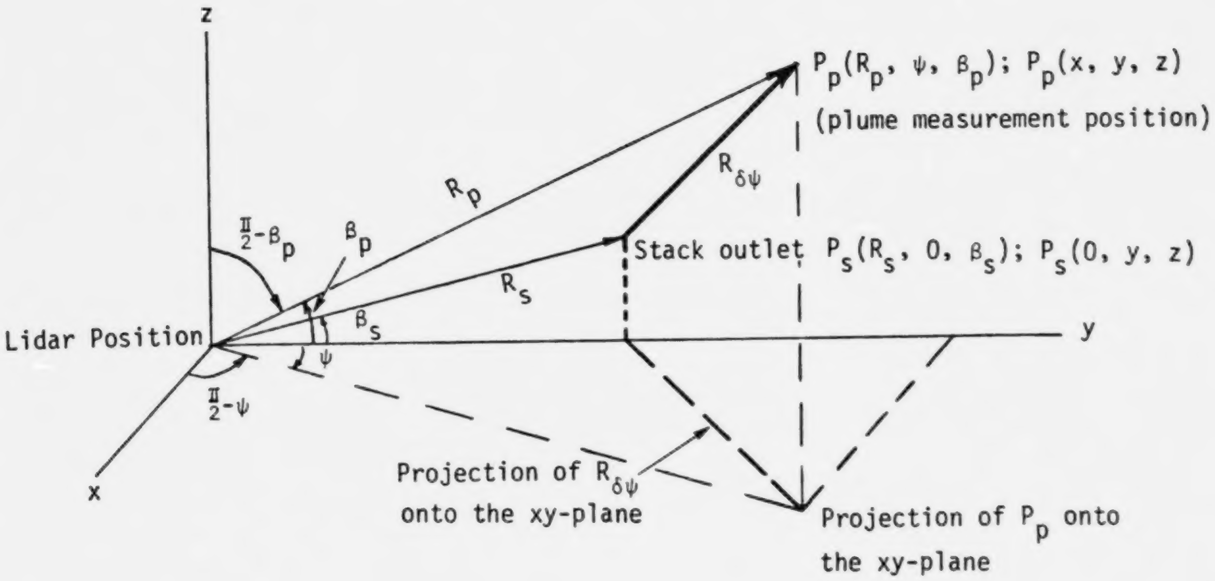
This equation is subjected to a coordinate transformation from rectangular to spherical coordinates by the following:

$$x = R\text{Sin}\beta\text{Cos}\psi, \quad y = R\text{Sin}\beta\text{Sin}\psi, \quad z = R\text{Cos}\beta$$

Applying the angle definition given in Figure VIII-1, Equation (VIII-2) becomes

$$R_{\delta\psi} = [R_p\text{Sin}(\tfrac{\pi}{2} - \beta_p)\text{Cos}(\tfrac{\pi}{2} - \psi) - 0)^2 + (R_p\text{Sin}(\tfrac{\pi}{2} - \beta_p)\text{Sin}(\tfrac{\pi}{2} - \psi)$$

$$- R_s\text{Sin}(\tfrac{\pi}{2} - \beta_s)\text{Sin}(\tfrac{\pi}{2} - \psi))^2 + (R_p\text{Cos}(\tfrac{\pi}{2} - \beta_p) - R_s\text{Cos}(\tfrac{\pi}{2} - \beta_s))^2]^{\frac{1}{2}}$$


z
$P_p(R_p, \psi, \beta_p)$; $P_p(x, y, z)$
(plume measurement position)
R_p
$R_{\delta\psi}$
$\frac{\pi}{2}-\beta_p$
β_p
Stack outlet $P_s(R_s, 0, \beta_s)$; $P_s(0, y, z)$
R_s
β_s
Lidar Position
ψ
y
$\frac{\pi}{2}-\psi$
x
Projection of $R_{\delta\psi}$ onto the xy-plane
Projection of P_p onto the xy-plane

The mathematical variables or functions are defined as follows:

$R_{\delta\psi}$ = the range from the emissions point, P_s, to the plume monitoring point or position, P_p.

R_s = the range from the lidar to the source or stack outlet.

β_s = the elevation angle of the lidar line-of-sight above the horizontal plane, to the stack outlet.

R_p = the range from the lidar to the plume monitoring point.

β_p = the elevation angle of the lidar line-of-sight above the horizontal plane, to the plume monitoring point.

ψ = the azimuthal angle, in the horizontal plane, of the lidar line-of-sight measured from the y-axis which contains the lidar and stack outlet.

$P_s(R_s, 0, \beta_s)$ = Coordinates of the stack outlet in the spherical coordinate system.

$P_p(R_s, \psi, \beta_p)$ = Coordinates of the plume monitoring point in the spherical coordinate system.

Figure VIII-1. Range Calculation for Plume Measurement Position

Using trigonometric relationships, the following is obtained:

$$\mathrm{Sin}(\tfrac{\pi}{2} - \psi) = 1 \text{ for } \psi = 0, \qquad \mathrm{Sin}(\tfrac{\pi}{2} - \beta) = \mathrm{Cos}\ \beta,$$

$$\mathrm{Cos}(\tfrac{\pi}{2} - \beta) = \mathrm{Sin}\ \beta, \qquad \mathrm{Cos}(\tfrac{\pi}{2} - \psi) = \mathrm{Sin}\ \psi.$$

With these expressons, $R_{\delta\psi}$ becomes

$$R_{\delta\psi} = [(R_p \mathrm{Cos}\beta_p \mathrm{Sin}\psi)^2 + (R_p \mathrm{Cos}\beta_p \mathrm{Cos}\psi - R_s \mathrm{Cos}\beta_s)^2 + (R_p \mathrm{Sin}\beta_p - R_s \mathrm{Sin}\beta_s)^2]^{\frac{1}{2}}$$

Finally, this equation is simplified to the following:

$$R_{\delta\psi} = [R_p^{\ 2} + R_s^{\ 2} - 2R_pR_s(\mathrm{Cos}\beta_p \mathrm{Cos}\beta_s \mathrm{Cos}\psi + \mathrm{Sin}\beta_p \mathrm{Sin}\beta_s)]^{\frac{1}{2}} . \qquad \text{(VIII-3)}$$

If the lidar beam is aimed directly over the stack outlet, then $\psi = 0$ and $R_{\delta\psi} \rightarrow R_{\delta o}$, and Equation (VIII-3) becomes

$$R_{\delta o} = [R_p^{\ 2} + R_s^{\ 2} - 2R_pR_s \mathrm{Cos}(\beta_p - \beta_s)]^{\frac{1}{2}} . \qquad \text{(VIII-4)}$$

Equation (VIII-3) is used to calculate the distance from the stack outlet to the lidar's plume measurement position. For each position of the lidar line-of-sight, $R_{\delta\psi}$ is calculated and recorded while the tests are being conducted.

Detached Steam Plumes: When the water vapor in a hydrated plume condenses and becomes visible at a finite distance from the stack or source emissions outlet, the opacity of the emissions is measured in a region of the smoke plume just above the emissions outlet prior to the condensation of the water vapor. The condensation of the water vapor in the source emissions forms the steam plume which appears white, and is usually about 100% opacity.

During daylight hours the lidar operator can visually determine if the steam plume is detached from the source outlet. At night a high-intensity spotlight within the Omega-1 lidar is also used to determine if the steam plume is detached from the emissions outlet by repeatedly measuring plume opacity from the outlet to the steam plume along its longitudinal axis or center line and/or observing plume reflectance.

Once the determination of a detached steam plume has been confirmed, the lidar is aimed into the region of the plume between the outlet and the formation of the steam plume, usually about one-half a stack diameter above the outlet. The lidar transmitter/receiver is then scanned across the plume to locate the region of greatest plume opacity. Plume opacity is subsequently measured at this location. Aiming adjustments are made to the lidar's line-of-sight within the plume to correct changes in the location of the most dense region of the plume due to changes in wind direction and speed or if the detached steam plume moves closer to the source outlet encroaching on the most dense region of the plume. If the detached steam plume should move too close to the source outlet for the lidar to make interference-free opacity measurements, opacity data is not recorded. The location of the lidar's line-of-sight within the plume is recorded for each position while the tests are being conducted.

In the measurement of plume opacity from a sulfuric acid manufacturing facility, the lidar line-of-sight should be positioned within the most dense part of the plume which will not necessarily be at the emissions outlet. The characteristic sulfurous gas absorbs plume moisture forming sulfuric acid aerosols in the submicron size range.[50 51]. High values for the opacity can occur. Often the aerosol plume does not become visible for a few stack diameters away from the emissions outlet. This does not constitute a detached steam plume and should not be treated as such. However, opacity measurements are always made outside a steam plume, if one is present, in the residual portion of the overall plume.

Opacity Data Calculation and Analysis: Plume opacity O_p is calculated from lidar data (appropriate reference signal and plume data signals in a particular data run) using Equation (V-4),

$$O_p = 100\% \left[1 - \left(\frac{I_f}{R_f} \; \frac{R_n}{I_n} \right)^{\frac{1}{2}} \right] \qquad \text{(V-4)}$$

The associated standard deviation S_0 for the opacity value 0_p is calculated by Equation (V-15),

$$S_0 = \frac{1}{2}\left(\frac{I_f}{R_f}\;\frac{R_n}{I_n}\right)^{\frac{1}{2}}\left[\frac{S_{In}{}^2}{I_n{}^2} + \frac{S_{If}{}^2}{I_f{}^2} + \frac{S_{Rn}{}^2}{R_n{}^2} + \frac{S_{Rf}{}^2}{R_f{}^2}\right]^{\frac{1}{2}} \qquad \text{(V-15)}$$

The selection of pick intervals and the calculation of their respective avarage values is presented in Section V.

Opacity Data Acceptance/Rejection Criterion: The standard deviation value S_0 is an indicator of the integrity of the optical backscatter signals from the near-region and far-region of the lidar line-of-sight, and may be termed an atmospheric noise indicator.

In the course of reducing large amounts of lidar-measured opacity data, it was empirically or fundamentally determined that if S_0 is greater than 8% (based on 100% opacity, full-scale; calculated with the plume opacity, 0_p, for the selected near-region and far-region pick intervals), then the lidar backscatter signal is not reliable (too noisy) for an accurate opacity measurement.

In the computer processing of lidar data, individual opacity values, 0_p, are, on occassion, discarded if $S_0 > 8\%$ or if the quality of the plume data signal is such than an opacity calculation cannot be effectively performed. (An example of the latter case is shown in Figure V-14(c) where the plume data signal being analyzed would have no Area 1 or Area 2, i.e., no flat area for a pick interval in the near-region. This also applies to the far-region of the plume data signal.)

If S_0 is initially calculated to be greater than 8%, then the far pick interval is changed to the next interval of minimal average amplitude, usually farther away from the plume spike. If S_0 is still greater than 8%, then this procedure is repeated for the far pick interval. This procedure may also be repeated once again for the near pick interval. If S_0 remains greater than 8%, this plume data signal is discarded.

Elevation Angle Correction Criterion: To ensure true plume opacity for enforcement data collection, the effect of the elevation angle (angle of inclination of the lidar transmitter/receiver) of the laser beam passing through a vertical plume is taken into consideration in the opacity calculation carried out by the computer. The elevation angle is measured with respect to the longitudinal (vertical) axis of the stack. As shown in Figure VIII-2 the optical plume opacity is typically measured with the lidar along the inclined path L. The opacity value ultimately required is along path P, the horizontal thickness of the plume. The ratio of P to L is:

$$\frac{P}{L} = \text{Cos } \beta_p \quad . \qquad \text{(VIII-5)}$$

Using Lambert's exponential law of attenuation (also known as Bouger's law), the plume transmittance for the horizontal, corrected path is

$$T_{pc} = e^{-kp} \quad . \qquad \text{(VIII-6)}$$

The plume transmittance along the inclined path L is

$$T_p = e^{-kL} \ . \qquad \text{(VIII-7)}$$

Using Equation (VIII-5) for the ratio of P to L, Equation (VIII-7) becomes

$$T_p = e^{-kp/\text{Cos}\beta_p} \qquad \text{(VIII-8)}$$

Taking the natural logarithm of Equations (VIII-6) and (VIII-8),

$$\ln T_{pc} = -kp \qquad \text{(VIII-9)}$$

$$\ln T_p = \frac{-kp}{\text{Cos}\beta_p}$$

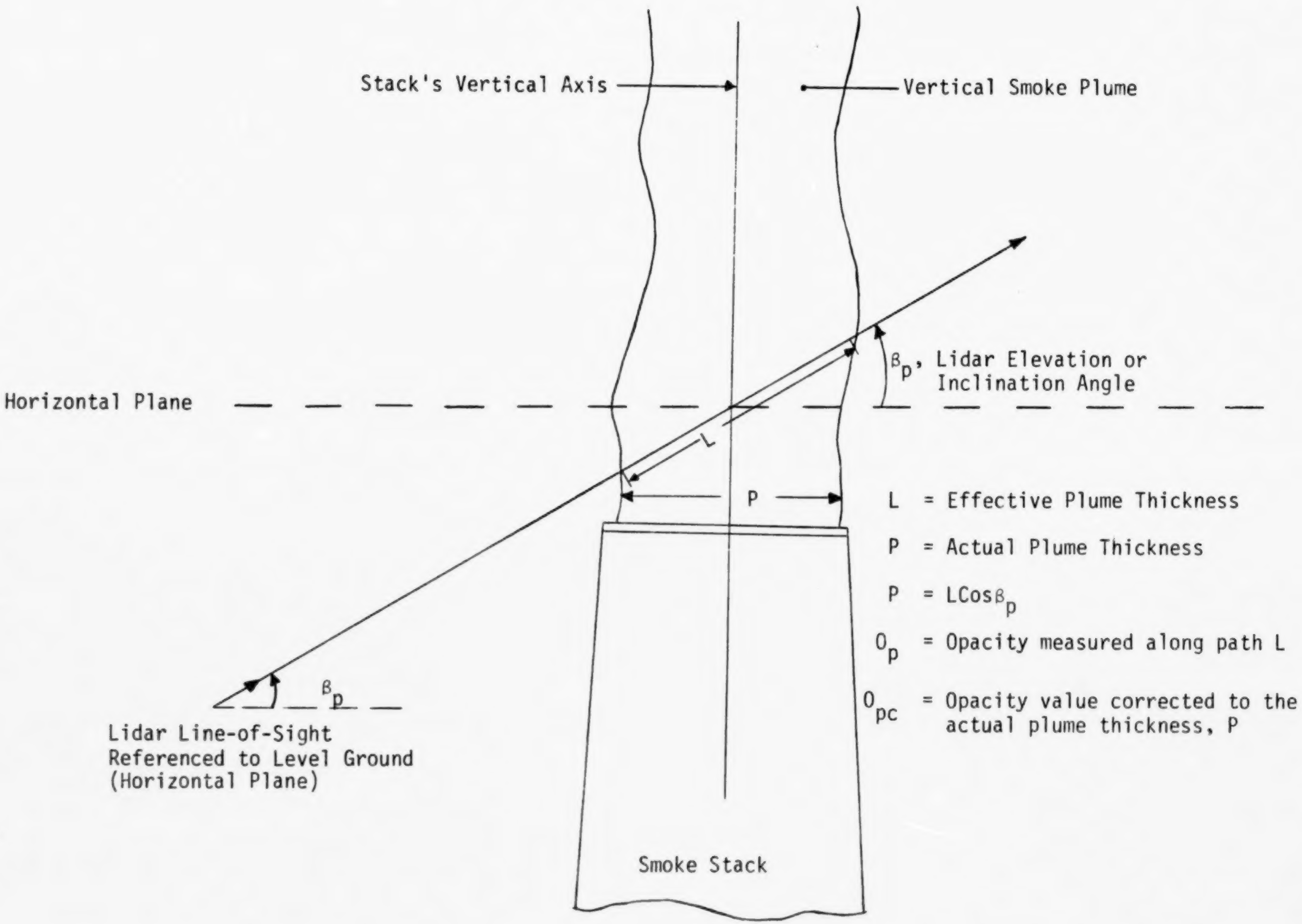
$$(\ln T_p)\text{Cos}\beta_p = -kp \quad . \qquad \text{(VIII-10)}$$

Equating Equations (VIII-9) and (VIII-10), the following is obtained:

$$\ln T_{pc} = (\ln T_p)\text{Cos}\beta_p ,$$

and by taking the antilog,

$$T_{pc} = (T_p)^{\text{Cos}\beta_p} , \qquad \text{(VIII-11)}$$


Stack's Vertical Axis
Vertical Smoke Plume
β_p, Lidar Elevation or Inclination Angle
Horizontal Plane
L
P
β_p
Lidar Line-of-Sight Referenced to Level Ground (Horizontal Plane)
Smoke Stack

L = Effective Plume Thickness

P = Actual Plume Thickness

$P = L \cos \beta_p$

O_p = Opacity measured along path L

O_{pc} = Opacity value corrected to the actual plume thickness, P

Figure VIII-2. Elevation Angle Correction for Vertical Plumes.

where the expression is independent of the absolute magnitudes of the paths P and L.

By the definition of opacity in terms of transmittance

$$T_{pc} = 1 - 0_{pc} \quad , \qquad T_p = 1 - 0_p \quad . \qquad \text{(VIII-12)}$$

Using these, Equation (VIII-11) becomes

$$(1 - 0_{pc}) = (1 - 0_p)^{\text{Cos}\beta_p} \quad .$$

Solving for 0_{pc}:

$$0_{pc} = 1 - (1 - 0_p)^{\text{Cos}\beta_p} \; , \qquad \text{(VIII-13)}$$

where:

β_p = Lidar elevation or inclination angle,

0_p = Opacity value measured along path L,

0_{pc} = Opacity value corrected to the actual plume thickness, P.

The opacity value 0_p for the lidar path L through the plume is mathematically modified by Equation (VIII-13) to obtain the opacity value 0_{pc} for the actual plume (horizontal) path or thickness.

It was elected to make this correction if the effect of the elevation angle would approach an error of 1% in plume opacity. To determine what elevation angle values require the correction, Equation (VIII-13) is solved for β_p:

$$(1 - 0_p)^{\text{Cos}\beta_p} = (1 - 0_{pc}).$$

Taking the natural logarithm of both sides, this equation becomes:

$$\ln (1 - 0_p)^{\text{Cos}\beta_p} = \ln (1 - 0_{pc}),$$

$$\text{Cos}\beta_p \ln (1 - 0_p) = \ln (1 - 0_{pc}),$$

$$\text{Cos } \beta_p = \frac{\ln (1 - 0_{pc})}{\ln (1 - 0_p)} \quad ,$$

$$\beta_p = \mathrm{Cos}^{-1}\left[\frac{\ln (1 - 0_{pc})}{\ln (1 - 0_p)}\right]. \qquad \text{(VIII-14)}$$

It was elected to make this correction if the effect of the elevation angle would approach an error of 1% in plume opacity.

$$0_p - 0_{pc} = 0.01 \qquad \text{(VIII-15)}$$

$$0_{pc} = 0_p - 0.01$$

Making the substitution, Equation (VIII-14) becomes

$$\beta_p = \mathrm{Cos}^{-1}\left[\frac{\ln (1 - (0_p - 0.01))}{\ln (1 - 0_p)}\right]$$

$$\beta_p = \mathrm{Cos}^{-1}\left[\frac{\ln (1.01 - 0_p)}{\ln (1 - 0_p)}\right]. \qquad \text{(VIII-16)}$$

Equation (VIII-16) is plotted in Figure VIII-3. The angle at which the correction must be carried out to maintain the 1% error is a function of plume opacity. In Figure VIII-3 no correction is required for the β_p values below the curve, as a function of opacity. Above the curve, correction is required. In terms of an inequality, if the elevation or inclination angle β_p is greater than or equal to the value calculated in Equation (VIII-16),

$$\beta_p \geq \mathrm{Cos}^{-1}\left[\frac{\ln (1.01 - 0_p)}{\ln (1 - 0_p)}\right] \qquad \text{(VIII-17)}$$

then the correction is performed using Equation (VIII-13). So far in practice in the field, the lidar pedestal elevation angle values have usually ranged from +3° to +12° because of the Omega-1 Lidar's ability to determine opacity values over reasonably long ranges from the stationary source under investigation.

A given 0_{pc} calculated with Equation (VIII-13) shall be used in place of its respective 0_p value in the Opacity Data Reduction Mechanism given earlier in this section.

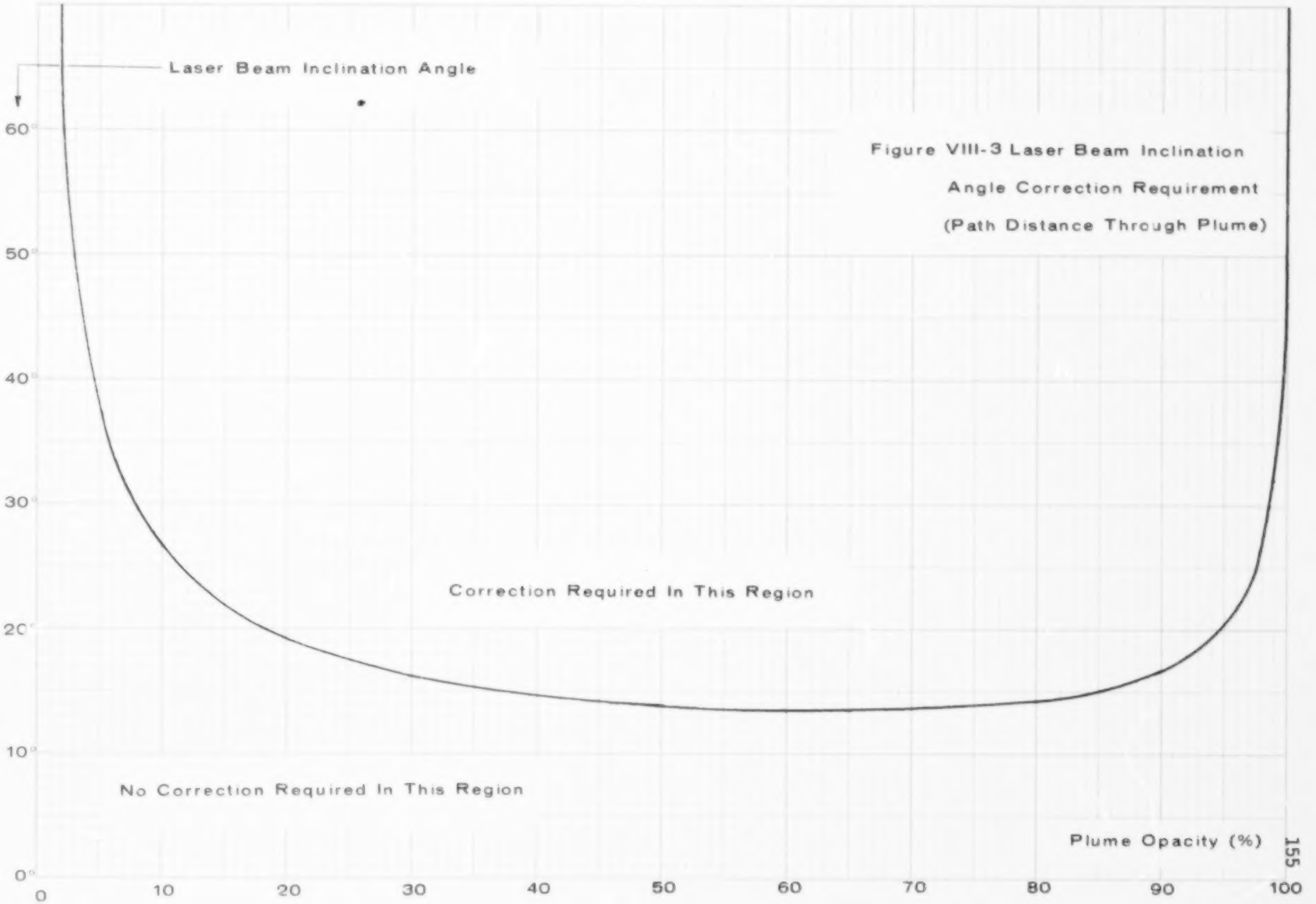


Figure VIII-3 Laser Beam Inclination Angle Correction Requirement (Path Distance Through Plume)

Azimuth Angle Correction Criterion: When measuring the opacity in the residual region of an attached steam plume, the lidar shall be positioned in relation to the source or stack so that the lidar line-of-sight is nearly perpendicular to the direction of the horizon drift of the plume, to the extent practical. This procedure will essentially keep the lidar line-of-sight distance through the plume equal to the actual plume thickness at the point of opacity measurement. However, if the direction or drift of the plume should change so that the lidar line-of-sight does not pass through the plume approximately perpendicular, then the azimuthal angle correction is made to the calculated opacity values, O_p, obtained under this condition. The geometry of this correction is defined in Figure VIII-4. This procedure is used to determine the need for the correction, calculate the correction, and document the point or location in the plume at which the opacity was measured.

In the derivation of the mathematical expression for this correction, the angle α in Figure VIII-4(a), must be calculated in terms of parameters that are easily measured within the lidar. In general, because of plume rise coupled with plume drift, the angle α does not lie a horizontal plane parallel to and raised above the xy-plane of the three-dimensional coordinate system.

Assume unit (length of one) lines drawn along the range vectors R_p, to the opacity measurement position P_p within the plume, and R_a, to the position P_a within the plume selected to measure the plume drift angle [Figure VIII-4].

Let R_{pa} be defined as the line connecting the ends of these two unit lines. The projections of these unit lines onto the xy-plane is $\mathrm{Cos}\beta_p$ and $\mathrm{Cos}\beta_a$. The projection of angle α onto the xy-plane is called α'. The projection of the line R_{pa} onto the xy-plane is calculated to be

$$R'_{pa} = \left[\mathrm{Cos}^2\beta_p + \mathrm{Cos}^2\beta_a - 2\mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' \right]^{\frac{1}{2}}$$

The square of the length of R_{pa} is given as

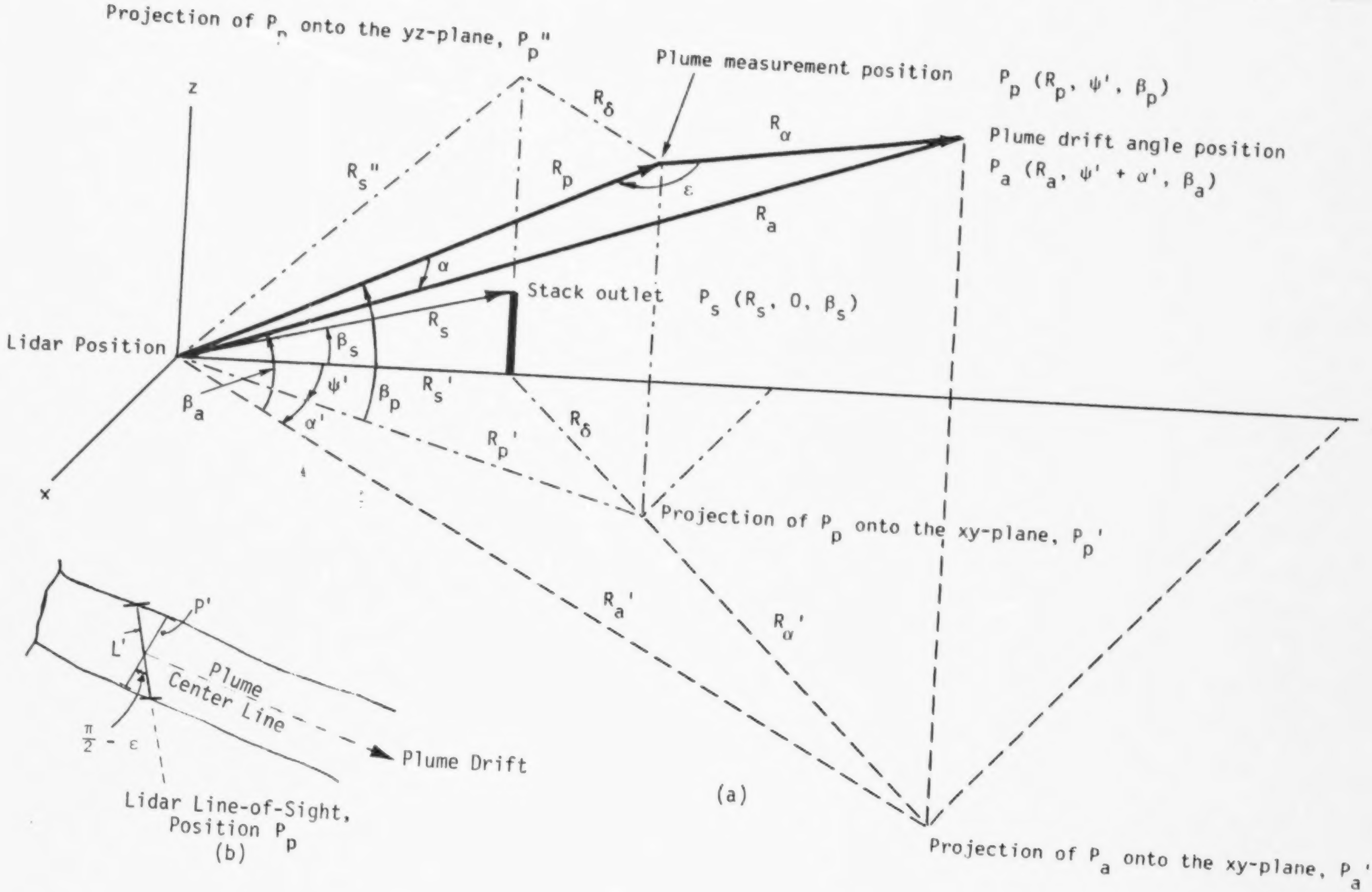

Projection of P_p onto the yz-plane, P_p''
Plume measurement position
P_p (R_p, ψ', β_p)
Plume drift angle position
P_a (R_a, ψ' + α', β_a)
z
R_δ
R_α
R_s''
R_p
ε
R_a
α
Stack outlet
P_s (R_s, 0, β_s)
Lidar Position
R_s
β_s
ψ'
β_p
R_s'
β_a
α'
R_δ
y
R_p'
x
Projection of P_p onto the xy-plane, P_p'
P'
L'
R_a'
R_α'
Plume
Center Line
$\frac{\pi}{2}$ - ε
Plume Drift
(a)
Lidar Line-of-Sight,
Position P_p
(b)
Projection of P_a onto the xy-plane, P_a'

Figure VIII - 4. Correction in Opacity for Drift of the Residual Region of an Attached Steam Plume.

$$R_{pa}{}^2 = \mathrm{Cos}^2\beta_p + \mathrm{Cos}^2\beta_a - 2\mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' + (\mathrm{Sin}\beta_a - \mathrm{Sin}\beta_p)^2 \quad .$$

By expanding and collecting terms,

$$R_{pa}{}^2 = 2 - 2\ \mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' - 2\ \mathrm{Sin}\beta_p\mathrm{Sin}\beta_a .$$

Using the appropriate trigometric relations for a plane triangle, Cosα is calculated:

$$\mathrm{Cos}\alpha = \frac{1 + 1 - (2 - 2\ \mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' - 2\ \mathrm{Sin}\beta_p\mathrm{Sin}\beta_a)}{2\cdot 1\cdot 1},$$

which reduces to

$$\mathrm{Cos}\alpha = \mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' + \mathrm{Sin}\beta_p\mathrm{Sin}\beta_a ,$$

$$\alpha = \mathrm{Cos}^{-1}\ [\mathrm{Cos}\beta_p\mathrm{Cos}\beta_a\mathrm{Cos}\alpha' + \mathrm{Sin}\beta_p\mathrm{Sin}\beta_a]. \qquad \text{(VIII-18)}$$

Using the law of cosines, R_α, the distance along the plume from P_p to P_a, is calculated as

$$R_\alpha = [R_p{}^2 + R_a{}^2 - 2\ R_pR_a\mathrm{Cos}\alpha]\ ^{1/2} \qquad \text{(VIII-19)}$$

From the law of sines, the plume drift angle ε is obtained:

$$\frac{\mathrm{Sin}\ \varepsilon}{R_a} = \frac{\mathrm{Sin}\ \alpha}{R_\alpha},$$

and

$$\varepsilon = \mathrm{Sin}^{-1}\left[\frac{R_a\ \mathrm{Sin}\alpha}{R_\alpha}\right] \qquad \text{(VIII-20)}$$

The distance, R_δ, from the stack outlet to the point P_p [Figure VIII-4], projected onto the xy-plane is obtained by the law of cosines

$$R_\delta = (R_s'^2 + R_p'^2 - 2\ R_s'R_p'\mathrm{Cos}\psi')^{1/2} \quad , \qquad \text{(VIII-21)}$$

where:

ψ' = the angle in the xy-plane measured from the stack P_s', to the plume measurement position, P_p', measured at the lidar pedestal.

$$R'_s = R_s \mathrm{Cos}\beta_s$$

$$R'_p = R_p \mathrm{Cos}\beta_p .$$

Finally, Equation (VIII-8) becomes

$$R_\delta = (R_s{}^2\mathrm{Cos}^2\beta_s + R_p{}^2\mathrm{Cos}^2\beta_p - 2\, R_s R_p \mathrm{Cos}\beta_s \mathrm{Cos}\beta_p \mathrm{Cos}\psi')^{\frac{1}{2}} \qquad \text{(VIII-22)}$$

In the special case where the plume center line between the opacity measurement point, P_p, and the drift angle position, P_a, is horizontal to the ground (xy-plane), Equation (VIII-23) may be used to calculate ε rather than Equation (VIII-20):

$$\varepsilon = \mathrm{Cos}^{-1}\left[\frac{R_p{}^2 + R_\delta{}^2 - R''^2_s}{2\, R_p R_\delta}\right], \qquad \text{(VIII-23)}$$

where:

$$R''_s = (R'^2_s + R_p{}^2\mathrm{Sin}^2\beta_p)^{\frac{1}{2}}$$

$$R''_s = (R_s{}^2\ \mathrm{Cos}^2\beta_s + R_p{}^2\mathrm{Sin}^2\beta_p)^{\frac{1}{2}}$$

If the angle ε is such that $\varepsilon \leq 30°$ or $\varepsilon \geq 150°$, the azimuth correction is not performed and the associated opacity value is discarded.

The geometry of the azimuth correction for opacity is shown in Figure VIII-4(b). L' is the path through the plume along which the lidar measures opacity O_p. P' is the path through the plume perpendicular to the plume center line. The plume drift angle, ε, is the angle between the plume center line and the lidar measurement path L'. If the plume drift is perpendicular to the lidar line-of-sight, then $\varepsilon = \pi/2$.

In a mathematical derivation similar to that of Equation (VIII-17), it is easily shown that if the plume drift angle is greater than or equal to the value,

$$\varepsilon \geq \mathrm{Sin}^{-1}\left[\frac{\ln(1.01 - O_p)}{\ln(1 - O_p)}\right], \qquad \text{(VIII-24)}$$

then the azimuth correction is performed. The correction of an opacity value, 0_p, for azimuth angle is derived from the geometry in Figure VIII-4(b). The ratio of P′ to L′ is:

$$\frac{P'}{L'} = \mathrm{Cos}\ (\tfrac{\pi}{2} - \varepsilon)\ . \qquad \text{(VIII-25)}$$

Using Lambert's exponential law of attenuation, the plume transmittance for the corrected path is

$$T_{pc} = e^{-kp'}\ . \qquad \text{(VIII-26)}$$

The plume transmittance along path L′ is

$$T_p = e^{-kL'} \qquad \text{(VIII-27)}$$

Using Equation (VIII-25), Equation (VIII-27) becomes

$$T_p = e^{-kp'/\mathrm{Cos}\ (\frac{\pi}{2} - \varepsilon)} = e^{-kp'/\mathrm{Sin}\varepsilon}\ . \qquad \text{(VIII-28)}$$

Taking the natural logarithm of Equation (VIII-26) and (VIII-28)

$$\ln T_{pc} = kp' \qquad \text{(VIII-29)}$$

$$\ln T_p = \frac{-kp'}{\mathrm{Sin}\varepsilon}$$

$$(\ln T_p)\mathrm{Sin}\varepsilon = -kp' \qquad \text{(VIII-30)}$$

Equating Equation (VIII-29) and (VIII-30):

$$\ln T_{pc} = (\ln T_p)\mathrm{Sin}\varepsilon,$$

and by taking the antilog,

$$T_{pc} = (T_p)^{\mathrm{Sin}\varepsilon}, \qquad \text{(VIII-31)}$$

which is independent of the plume path length P′ and L′.

By definition of opacity as a function of transmittance

$$T_{pc} = 1 - 0_{pc}, \quad T_p = 1 - 0_p \ . \qquad \text{(VIII-32)}$$

With these, Equation (VIII-31) becomes

$$(1 - 0_{pc}) = (1 - 0_p)^{\text{Sin}\varepsilon} \qquad \text{(VIII-33)}$$

and

$$0_{pc} = 1 - (1 - 0_p)^{\text{Sin}\varepsilon} \ .$$

This correction maintains the difference, $0_p - 0_{pc}$, to within 1% opacity.

If the azimuth angle correction is performed on an opacity value, 0_p, then the elevation angle correction given in Equation (VIII-13), need not be performed.

Definition of Actual Plume Opacity Using Lidar Measurements: When a lidar-measured opacity value, 0_p, is calculated [Equation (V-4)], an associated standard deviation value, S_o, is also calculated [Equation (V-15)]. This parameter, S_o, is an indication of the magnitude of atmospheric signal noise along the lidar line-of-sight.

In order to apply S_o, to the EPA enforcement program, its significance in the definition of actual plume opacity has been derived from the results of the Screen Target Test and the Statistical Covariance Test [Section VI]. For the Screen Target Test, the distribution of opacity values, 0_p, about the average of the opacity values, $\bar{0}_p$, closely approximates a gaussian or normal distribution[39]. The Statistical Covariance Test showed that $\bar{S}_o$, average of the standard deviation values, without covariance terms [Equation (V-15)] was calculated to be equal to or slightly greater than the $\bar{S}_o$ with the covariance terms [Equation (V-10)]. For a gaussian distribution of opacity values, the probability of any 0_p being within the range of $\pm \bar{S}_o$ (±1 standard deviation) of the average opacity, $\bar{0}_p$, is about 68%. The probability that 0_p falls within $\pm 2\bar{S}_o$ of $\bar{0}_p$, correspondingly, is about 95%. The probability that a 0_p falls within $\pm 3\bar{S}_o$ of $\bar{0}_p$ is 99.67%, that 0_p falls within $\pm 4 \bar{S}_o$ of $\bar{0}_p$ is 99.994%.

These facts were used to clearly define actual plume opacity when using lidar measurements. Also, based on the Lidar-Reference Method 9 Collaborative Test and the definition of correlation, which states that 0% opacity determined by Reference Method 9 [Section III]* is defined as being less than or equal to 5% opacity by lidar measurement, opacity values calculated from lidar data using Alternate Method 1, shall be lowered by 5% to insure consistency between these two methods.

Actual plume opacity, O_{pa}, is calculated using the corrected lidar opacity value, O_{pc} (O_p if no corrections or compensations are required), the standard deviation, S_o, and the 5% correlation value discussed above:

$$O_{pa} = O_{pc} - (2\ S_o + 5\%)\ . \tag{VIII-34}$$

The 5% value is larger than the 4% value obtained from the collaborative test (the lidar average opacity was 4% higher than the average of the VEOs for black smoke and 8% lower for white smoke).

If the actual opacity value or the average of a set of actual opacity values is greater than an opacity value established in an NSPS, State or local regulation, then the probability that the stationary source is in noncompliance with the regulation is greater than 95%. If lidar determines noncompliance for actual plume opacity, so will Reference Method 9.

Actual Plume Opacity Data Reduction Mechanism: The temporal length of an individual data run may extend from 1 or 2 minutes, such as for intermittent sources, to over an hour or even longer usually depending upon the characteristics and variability of the source emissions. The lidar data rate is nominally set at one opacity measurement every 10 seconds throughout a given data run. However, for variable conditions of smoke plume or weather, the lidar pulse rate or pulse repetition frequency (prf) should be set higher than 1 pulse every 10 seconds, to possibly 1 pulse every 4 or 5 seconds.

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* *Collaborative tests involving mass emissions and plume opacity showed that zero plume opacity does not always equate to zero visible emissions. Lidar is more sensitive to low-level visible emissions than the visible emissions observer.*

The manner in which the actual plume opacity data values [Equation VIII-34)] from a given data run are reduced is a function of the air quality regulation or standard to be enforced. When an NSPS or a given state or local regulation [State Implementation Plan (SIP)] specifies a maximum permitted opacity value over a fixed time period (Example: Plume opacity shall not exceed 50% for a continuous period of more than 5 minutes in any 60 consecutive minutes), then that time period or interval shall be used in the reduction of the opacity data. If the respective standard or regulation specifies an opacity limit for any I-minute interval and the data run were I minutes in length, then all the opacity values, measured on the nominal 5 to 10-second repetitive cycle or prf and processed for this interval, are averaged yielding an average (actual plume) opacity for this interval.

The average of the actual plume opacity, $\bar{0}_{pa}$, for the I-minute time interval is calculated as the average of the consecutive (in time) individual lidar-measured opacity values, 0_{pa}, by using Equation (VIII-35). The I-minute time interval is called the "averaging interval".

$$\bar{0}_{pa} = \frac{1}{n} \sum_{k=1}^{n} \left[0_{pa}\right]_k \quad , \qquad \text{(VIII-35)}$$

where: $\left[0_{pa}\right]_k$ = the kth opacity value in the (I-minute) averaging interval (k is a summary index),

Σ = the sum of the individual opacity values,

n = number of individual opacity values contained in the averaging interval,

$\bar{0}_{pa}$ = average opacity over the averaging interval.

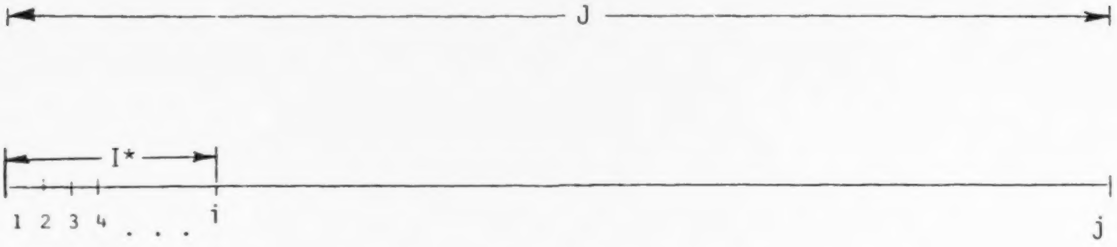
If the respective regulation specifies an opacity limit for an I-minute interval and the data run were J-minutes in length (J > I), then a running-average or progressive average is used to reduce the lidar opacity values for the data run. The mechanism for the running-average is shown in

Figure VIII-5. The I-minute interval is maintained constant in length (temporal) being moved along the entire length of the J-minute data run. If i opacity values, from 1 to i, have been averaged for the I-minute time interval by Eq (VIII-35), the running-average is performed by successively subtracting the mth value and adding the n + 1 value and calculating the average for those i opacity values again, then subtract the m + 1 value and add the n + 2 value and perform the calculation again, etc.

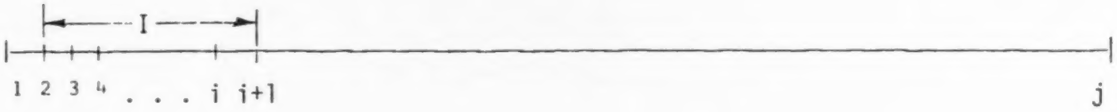
The running-average is a computational tool which locates the I-minute interval within J that has the highest average opacity. This applies directly to the example given above, i.e., the 5-minute period (I=5) in any 60-consecutive-minute period (J=60). The number of values averaged in this manner will not always be equal to a constant i, but the time interval I will be the same throughout J. A few of the i values may possibly be rejected due to the Opacity Data Acceptance/Rejection Criterion presented earlier in this section.

If, in a given averaging interval I, there is a temporal space or time period of 30 seconds where there are no opacity values, O_{pa}, then the average opacity, $\bar{O}_{pa}$, for that averaging interval is discarded, being invalid.

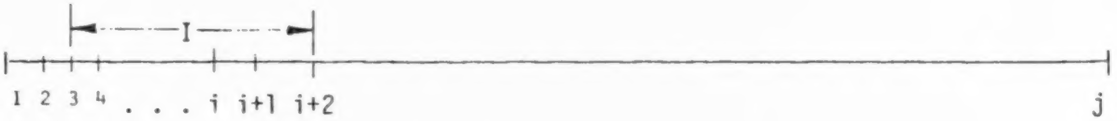
When the applicable regulation or standard specifies a maximum opacity value as a function of time, then the actual opacity values, measured on the nominal 5-to 10-second data rate, are reduced accordingly by computer. The time intervals over which the actual opacity values exceed the maximum specified in the regulation, are summed together within the specified consecutive or overall time period. If the summed time period exceeds the allowable time period, the source is in noncompliance. Example: Suppose the state regulation states that short-term occurrences shall exceed 50% opacity from a period aggregating no more than 5 minutes in any 60 consecutive minutes and/or no more than 20 minutes in any 24-hour period. The time intervals over which the actual plume opacity exceeded 50% are summed together. If the sum of the intervals exceeds 5 minutes in any 60 consecutive minutes then the source is in violation. The same holds true if the individual time intervals exceed 20 minutes in any 24-hour period.



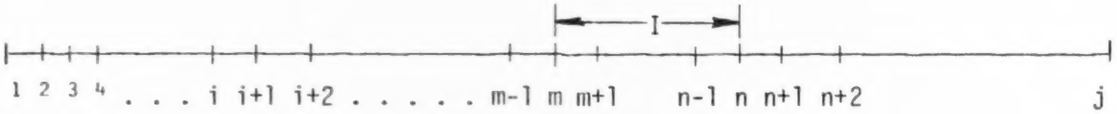
(a) First average opacity, $\overline{O}_p$, calculated for the i opacity values



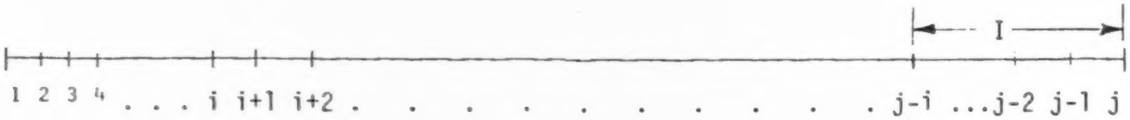
(b) Second average opacity calculated, first opacity value subtracted and the (i+1) value added.


I
1 2 3 4 . . . i i+1 i+2
j

(c) Third average opacity calculated, second opacity value subtracted and the (i+2) value added.


I
1 2 3 4 . . . i i+1 i+2 . . . . . m-1 m m+1 n-1 n n+1 n+2
j

(d) The mth average opacity calculated.


I
1 2 3 4 . . . i i+1 i+2 . . . . j-i ...j-2 j-1 j

(e) The last average opacity calculated over the time interval I.

*I is the averaging interval established by NSPS, State or Local Regulations.

Figure VIII-5. Pictoral Diagram of the Running Average.

If there is no applicable state or local air pollution regulation specifying how the actual plume opacity data is to be reduced, then the 6-minute time interval of Reference Method 9 is used. The running-average technique described above is used to calculate the 6-minute interval which has the highest average opacity within a data run. Referring to Figure VIII-5, I is equal to 6 minutes and J is 6 minutes or longer.

The opacity of intermittent visible emissions and cyclic processes is measured over a period of at least 3 or 4 cycles or a longer time considered adequate to determine compliance/non-compliance with the applicable regulation. A cyclic process is defined in Figure VIII-6.

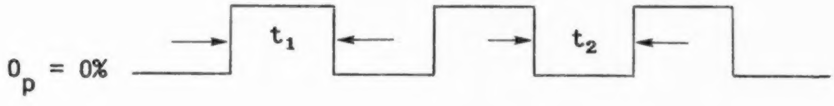


Figure VIII-6 Cyclic Process

If the regulation, such as a state or local regulation in an approved State Implementation Plan (SIP), specifies an opacity limit as a function of time, the times for the actual plume opacity values, O_{pa}, shall be added together in accordance with the requirements of the regulation.

If there is no applicable NSPS, state, or local regulation, the 6-min interval will be used as described above. If the time period of a given cycle is less than 6 minutes, the opacity values for this period are added to sufficient number of zeros to obtain the 6-minute period. The average opacity is computed from the opacity values and the added zeros. For example, if a particular cycle was 4 min in length there would be 24 opacity values (4 min x 6 opacity values/min), then 12 zeros would have to be added to bring the total to the 36 required values (6 min x 6 opacity values/min).

In support of 40 CFR Part 51 with opacity limits as a function of time, Alternate Method 1 will be employed by summing the respective opacity measurement time intervals for the required period of time.

Lidar Field Performance Verification: As it is with any quantitative measurement instrument, overall system calibration is important for the lidar. A viable means of checking and monitoring system performance is a necessity in the enforcement application. Extensive performance verification is carried out to support the field data gathered for use as evidentiary material.

The Omega-1 Lidar has an optical generator (built-in calibration mechanism discussed in Section VI in detail) that tests the entire receiver, electronics, and data processing systems. This is accomplished by using a highly-controlled small solid state laser and light-emitting diodes (l.e.d.) to inject an optical signal, which simulates an actual lidar return signal from a given atmospheric path through a plume, or in clear air, into the receiver ahead of the PMT detector. The optical generator simulates real optical signals representing clear air or 0% opacity, 10, 20, 40, 60 and 80% opacities (nominal).

This test is carried out periodically in the field while the lidar is in use, requiring about 3 to 4 minutes to perform. Each of the abovementioned optical signals is fed into the lidar receiver, the resultant opacity is calculated in just the same manner as the real data collected in the field, and each value is recorded on magnetic tape (actual lidar-simulated signal), paper printout, and in the operations log book (discussed later in this section).

If the lidar-measured opacity value is not within ± 3% (based on full-scale, 100% opacity) of the actual value of the optical generator input of each of the two video channels:

Linear Channel - ± 3% over the opacity range of 0% through 80% (optical generator values), Logarithmic Channel - ± 3% over the opacity range of 20% through 80% (optical generator values),

then the lidar's proper performance has not verified and remedial action is taken.

The optical generator itself is periodically (once per month) subjected to an exacting calibration in which all signal levels are measured to within a fraction of a percent of the required values.

The results of the performance evaluation and the calibration tests are discussed at length in Section VI.

Lidar Data Analysis Record: While the lidar data analysis and reduction are being conducted, permanent records are initiated and maintained. In these records, the paper output from a computer printer, the measured or calculated values for I_n, S_{In}; I_f, S_{If}; R_n, S_{Rn}; R_f, S_{Rf}; R_s, β_s, R_p, β_p, β_a, R_a; ψ', α', R_δ, R_α, ψ, $R_{\delta\psi}$; α; ε; O_p, S_o, O_{pc}, O_{pa}, along with the respective units (meters, nanoseconds, etc.) are recorded for each final opacity calculation. The data processing operations that were used to calculate the final opacity value from a given plume data signal are easily determined from these records. During the data reduction process the values of $\bar{O}_{pa}$ (which were calculated from the applicable O_{pa} values) and $\bar{S}_o$ (average of the standard deviations) are documented along with the applicable parameters used in performing the running-average. The date and time that each lidar data signal was obtained, its respective assigned control number, its magnetic tape file address, and the tape file address of the respective reference measurement are also recorded for each final opacity calculation.

The identity of each criterion used in the data analysis and identity of any opacity values rejected are recorded for each applicable opacity value.

Lidar Log Book: A special purpose logbook entitled "Lidar Log of Operation" has been designed to be a permanent record of the lidar activities for evidentiary purposes. The cover [Figure VIII-7] of each logbook contains the custody number, the dates it was used, and the number of the next logbook in sequence.

A control number is assigned for each stationary source monitored with the lidar. This number is assigned on the Lidar Log Control Number Tabulation [Figure VIII-8], and is also recorded for each individual lidar backscatter signal in the identification block on magnetic tape. This number is used for evidentiary purposes.

The required data for each source under investigation is specified and recorded on the "Lidar Log of Operations" [Figure VIII-9 and 10]. This includes source description/characteristics, local meteorological conditions measured at the lidar's position, and the data record log. The calibration record is in Figure VIII-9 which gives the calibrated opacity of the optical generator, the opacity value calculated by the lidar computer using the optical generator as the source and the file address on magnetic tape where the data were recorded.

The forms shown in Figures VIII-7 through 10 are bound in a sewn logbook and are subject to EPA-NEIC document control and chain-of-custody regulations/procedures.

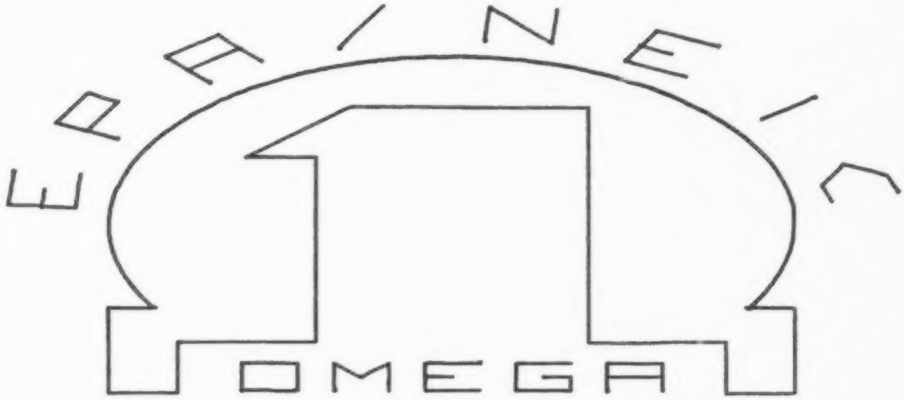
As required by the chain-of-custody procedures for evidentiary material, the magnetic tapes (Hewlett Packard cassettes containing computer programs and the 8.5-inch 9-track data tapes) are stored and carried in specialized magnetic shielded boxes to prevent accidental erasure and the pickup of any spurious noise. When the data tapes are returned to EPA-NEIC for data processing, they are stored in standard shielded tape racks in the computer laboratory.

Data Presentation/Final Report Format: The opacity values, O_p, the standard deviation values, S_o, and other parameters obtained through data analysis on the NEIC laboratory computer are documented in an EPA-NEIC data analysis report. For each data run these values are presented in tabular

LIDAR LOG OF OPERATIONS

Log Book Number_____

from / / to / /


EPA / NEIC
OMEGA

Next Log Book Number_______

Figure VIII-7 Cover Of Lidar Log Book

LIDAR LOG CONTROL NUMBER TABULATION

Log Book Number-________

(Assign a CONTROL NUMBER to each individual source under test)

CONTROL NUMBER	DATE ASSIGNED	PROJECT	CITY, STATE

continued on next page

Figure VIII-8 Lidar Log Control Number Tabulation

LIDAR LOG OF OPERATIONS

Control number: OMEGA-____________

Facility name and location:

At the field site on / / **from** ______________ **to** ______________ **(local time)**

Location of LIDAR:

Direction to source ______________ Range to source ______________ km

Laser inclination (+ angle is up; horizontal is 0°) ______________

Source type and official designation:

Plume characteristics (color, shape, steam present, etc.):

Wind speed: begin ________ km/hr end ________ km/hr **Wind direction:** begin ________ end ________

Air temperature: begin ________ °C end ________ °C **Relative humidity:** begin ________ % end ________ %

Barometer: begin ________ end ________ **Visibility:** begin ________ km end ________ km

Cloud cover: begin ______________ end ______________

Data records made in field (tapes, printouts, photo's, etc.):

MAGNETIC TAPES

tape#	track#	files

OPERATOR'S SIGNATURE: ______________________ **DATE:** __________

WITNESS SIGNATURE: ______________________ **DATE:** __________

Figure VIII-9 Lidar Log Of Operations-Sheet 1

LIDAR OPERATOR'S NOTES

(Include position of laser beam within plume-- attached plume, etc.)

LIDAR FUNCTION VERIFICATION Source: optical generator [ ] screens [ ]

Date of last calibration: ________ This test recorded on tape# ______ track# ________

	1	2	3	4	5	6	7	8
Calibrated opacity	____	____	____	____	____	____	____	____
Calculated opacity	____	____	____	____	____	____	____	____
Recorded on file	____	____	____	____	____	____	____	____

OPERATOR'S SIGNATURE: ________________________________ **DATE:** ________

WITNESS SIGNATURE: ________________________________ **DATE:** ________

Figure VIII-10 Lidar Log Of Operations-Sheet 2

form [Figure VIII-11] followed by graphic plots [Figures V-23 and V-24]. An identification header is printed across the top of the tabular form which provides the following information:

- EPA-NEIC identification block,
- EPA-NEIC Omega Control number (evidentiary parameter),
- Official designation for the stationary source,
- Facility name,
- Facility location,
- Location of the lidar during tests, and
- Length of the running-average interval I.

This tabular presentation provides the applicable data in columns identified as follows:

- Date of the data run - month/day/year,
- Time of the opacity measurement (nearest second),
- Opacity values (O_{pa}) calculated in %,
- Individual violation flag (****) indicating that the opacity value O_{pa} exceeded the NSPS or SIP regulation limit,
- Standard deviation SO (S_o) in % (full-scale),
- Average opacity ($\bar{O}_{pa}$) in % calculated over the running-average interval,
- Average standard deviation ($\bar{S}_o$) in % calculated over the running-average interval,
- Average opacity violation of flag (****) indicating that the average opacity value $\bar{O}_{pa}$ exceeded the NSPS or SIP regulation limit,

```
                         UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
                          NATIONAL ENFORCEMENT INVESTIGATIONS CENTER
                                   DENVER, COLORADO 80225

OMEGA-0028   XXXX STACK, COMPANY NAME,     CITY, STATE.      FROM LIDAR LOCATION.     FIVE MINUTE AVERAGES
   DATE        TIME    OPACITY  SO  VIOLATION  AVERAGE OPACITY  AVERAGE SO  VIOLATION  NUMBER DISCARDED

12/ 4/79   22:29:54      17     5                  20              4                     0 OF  66
12/ 4/79   22:29:59      19     4                  20              4                     0 OF  66
12/ 4/79   22:30: 4      18     4                  20              4                     0 OF  65
12/ 4/79   22:30: 8      15     4                  20              4                     0 OF  66
12/ 4/79   22:30:13      24     5                  20              4                     0 OF  65
12/ 4/79   22:30:17      23     4                  19              4                     0 OF  65
12/ 4/79   22:30:22      22     5                  19              4                     0 OF  65
12/ 4/79   22:30:27      22     5                  20              4                     0 OF  65
12/ 4/79   22:30:31      26     4                  20              4                     0 OF  65
12/ 4/79   22:30:36      33     4                  20              4                     0 OF  65
12/ 4/79   22:30:40      38     4                  20              4                     0 OF  65
12/ 4/79   22:30:45      42     3                  20              4                     0 OF  65
12/ 4/79   22:30:50      46     3                  20              4        ****         0 OF  65
12/ 4/79   22:30:54      47     3                  20              4        ****         0 OF  65
12/ 4/79   22:30:59      51     3                  21              4        ****         0 OF  65
12/ 4/79   22:31: 3      52     3                  21              4        ****         0 OF  65
12/ 4/79   22:31: 8      54     4                  22              4        ****         0 OF  65
12/ 4/79   22:31:13      59     3                  22              4        ****         0 OF  65
12/ 4/79   22:31:17      60     2                  23              4        ****         0 OF  65
12/ 4/79   22:31:22      58     3                  23              4        ****         0 OF  65
12/ 4/79   22:31:27      57     3                  24              4        ****         0 OF  65
12/ 4/79   22:31:31      56     2                  25              4        ****         0 OF  65
12/ 4/79   22:31:36      57     4                  25              4        ****         0 OF  65
12/ 4/79   22:31:40      56     4                  26              4        ****         0 OF  65
12/ 4/79   22:31:45      58     4                  26              4        ****         0 OF  65
12/ 4/79   22:31:50      58     3                  27              4        ****         0 OF  65
12/ 4/79   22:31:54      58     2                  28              4        ****         0 OF  65
12/ 4/79   22:31:59      54     4                  28              4        ****         0 OF  65
12/ 4/79   22:32: 3      59     2                  29              4        ****         0 OF  65
12/ 4/79   22:32: 8      63     3                  29              4        ****         0 OF  65
12/ 4/79   22:32:13      64     2                  30              4        ****         0 OF  65
12/ 4/79   22:32:17      66     2                  30              4        ****         0 OF  65
12/ 4/79   22:32:22      70     1                  31              4        ****         0 OF  65
12/ 4/79   22:32:27      68     2                  33              4        ****         0 OF  66
12/ 4/79   22:32:31      69     1                  34              4        ****         0 OF  66
12/ 4/79   22:32:36      69     4                  34              4        ****         0 OF  66
12/ 4/79   22:32:40      71     3                  35              4        ****         0 OF  66
12/ 4/79   22:32:45      70     1                  36              4        ****         0 OF  66
12/ 4/79   22:32:50      72     2                  37              4        ****         0 OF  66
12/ 4/79   22:32:54      77     5                  37              4        ****         0 OF  66
12/ 4/79   22:32:59      72     3                  38              4        ****         0 OF  66
12/ 4/79   22:33: 3      71     3                  39              4        ****         0 OF  66
12/ 4/79   22:33: 8      72     3                  40              4        ****         0 OF  66
12/ 4/79   22:33:13      73     4                  41              4        ****         0 OF  66
12/ 4/79   22:33:17      72     1                  42              4        ****         0 OF  66
12/ 4/79   22:33:22      75     5                  43              4        ****         0 OF  66
12/ 4/79   22:33:26      75     5                  43              4        ****         0 OF  66
12/ 4/79   22:33:31      71     2                  44              4        ****         0 OF  66
12/ 4/79   22:33:36      71     2                  45              4        ****         0 OF  66
12/ 4/79   22:33:40      72     4                  46              4        ****         0 OF  66
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Figure VIII-11 Omega-1 Lidar Opacity Data Final Report Format

- Number of opacity values (O_p) discarded due to the opacity Data Acceptance/Rejection Criterion.

The format of the tabular form given in Figure VIII-11 is slightly modified if the opacity values and time intervals are subject to aggregation in a standard or regulation being enforced.

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APPENDIX A

Part 60 - Standards of Performance For New Stationary Sources

Final Rule

Effective Date: June 22, 1977

will be limited to 10 minutes for an oral presentation exclusive of time consumed by questions from the panel for the Government and answers thereto.

An agenda showing the scheduling of the speakers will be made after outlines are received from the speakers, and copies of the agenda will be available free of charge at the hearing.

ROBERT A. BLEY,
Director, Legislation and Regulations Division.

[FR Doc.77-14622 Filed 5-20-77;8:45 am]

Title 28—Judicial Administration

CHAPTER I—DEPARTMENT OF JUSTICE

[Order No. 725-77]

PART 0—ORGANIZATION OF THE DEPARTMENT OF JUSTICE

Conduct of Legal Proceedings

AGENCY: Department of Justice.

ACTION: Final rule.

SUMMARY: Under 28 U.S.C. 515(a), Department of Justice attorneys, when specifically directed by the Attorney General, are authorized to conduct any kind of legal proceeding, including grand jury proceedings, which United States Attorneys are authorized by law to conduct, whether or not the attorney is a resident of the district where the proceeding is brought. Present regulations delegate certain of the Attorney General's authority under this statute to certain Department officials. This order broadens the authority delegated by the Attorney General expressly to include the designation of attorneys to conduct legal proceedings, and extends the delegation to all Divisions.

EFFECTIVE DATE: May 12, 1977.

FOR FURTHER INFORMATION CONTACT:

John M. Harmon, Acting Assistant Attorney General, Office of Legal Counsel, Department of Justice, Washington, D.C. 20530 (202-739-2041).

By virtue of the authority vested in me by 28 U.S.C. 509, 510 and 5 U.S.C. 301, Part 0 of Chapter I of Title 28, Code of Federal Regulations, is amended as follows:

1. A new § 0.13 is added at the end of Subpart B, to read as follows:

§ 0.13 Legal proceedings.

(a) Each Assistant Attorney General and Deputy Assistant Attorney General is authorized to exercise the authority of the Attorney General under 28 U.S.C. 515(a), in cases assigned to, conducted, handled, or supervised by such official, to designate Department attorneys to conduct any legal proceeding, civil or criminal, including grand jury proceedings [illegible] proceedings before committing magistrates, which United States attorneys are authorized by law to conduct, whether or not the designated attorney is a resident of the district in which the proceedings is brought.

(b) Each Assistant Attorney General is authorized to redelegate to Section Chiefs the authority delegated by paragraph (a) of this section, except that such redelegation shall not apply to the designation of attorneys to conduct grand jury proceedings.

§ 0.40 [Amended]

2. Paragraph (a) of § 0.40 of Subpart H is amended by deleting "designation of attorneys to present evidence to grand juries."

§ 0.43 [Revoked]

3. Section 0.43 of Subpart H is revoked.

§ 0.50 [Amended]

4. Paragraph (a) of § 0.50 of Subpart J, is amended by deleting "and designation of attorneys to present evidence to grand juries."

§ 0.60 [Revoked]

5. Section 0.60 of Subpart K is revoked.

(28 U.S.C. 509, 510 and 5 U.S.C. 301.)

Dated: May 12, 1977.

GRIFFIN B. BELL,
Attorney General.

[FR Doc.77-14545 Filed 5-20-77;8:45 am]

Title 38—Pensions, Bonuses, and Veterans' Relief

CHAPTER I—VETERANS ADMINISTRATION

PART 3—ADJUDICATION

Subpart B—Burial Benefits

HEARSE CHARGES FOR TRANSPORTING BODIES

AGENCY: Veterans Administration.

ACTION: Final Regulation.

SUMMARY: The VA has amended its regulation relating to hearse charges for transporting a body to place of burial.

EFFECTIVE DATE: May 11, 1977.

FOR FURTHER INFORMATION CONTACT:

Mr. T. H. Spindle, Chief, Regulations Staff, Compensation and Pension Service Veterans Administration, Washing, D.C. 20420 (202-389-3005).

SUPPLEMENTARY INFORMATION: On page 16839 of the FEDERAL REGISTER of March 30, 1977, there was published a notice of proposed regulatory development to amend § 3.1606(b) relating to hearse charges. When a person dies in a Veterans Administration facility to which he or she was properly admitted for hospital, nursing home or domicilliary care under 38 U.S.C. 610 or 611(a), the Veterans Administration is usually required to pay the cost of transporting the body to the place of burial. (38 U.S.C. 903) The Veterans Administration is also directed to pay the cost of transporting the body of certain veterans who die outside of a Veterans Administration facility when burial will be made in a National Cemetery. (38 U.S.C. 903)

Claims have been received for payment of charges for transporting a body by hearse over quite long distances when common carrier service was readily available. In these claims the hearse charges greatly exceeded the common carrier rate. Therefore, § 3.1606 is amended to provide that payment of hearse charges for transporting a body over long distances will be limited to prevailing common carrier rates where it is reasonable and customary for shipment to be made by common carrier. This limitation will not be for application where common carrier service is unavailable or where use of a common carrier would clearly be impractical. When a common carrier is used to transport a body, charges for use of a hearse to deliver the body to and from the carrier will be paid.

Interested persons were given 30 days in which to submit comments, suggestions or objections regarding the proposed regulation. No written comments have been received and the proposed regulation is hereby adopted without change and is set forth below.

NOTE.—The Veterans Administration has determined that this document does not contain a major proposal requiring preparation of an Economic Impact Statement under Executive Order 11821 and OMB Circular A-107.

Approved: May 11, 1977.

By direction of the Administrator.

RUFUS H. WILSON,
Deputy Administrator.

In § 3.1606, paragraph (b)(3) is added to read as follows:

§ 3.1606 Transportation items.

The transportation costs of those persons who come within the provisions of §§ 3.1600(g) and 3.1605 (a), (b), (c) and (d) may include the following:

* * * * *

(b) *Transported by hearse.* * * *

(3) Payment of hearse charges for transporting the remains over long distances are limited to prevailing common carrier rates when common carrier service is available and can be easily and effectively utilized.

[FR Doc.77-14558 Filed 5-20-77;8:45 am]

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

[FRL 715-8]

PART 60—STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES

Compliance With Standards and Maintenance Requirements

AGENCY: Environmental Protection Agency.

ACTION: Final rule.

SUMMARY: This action amends the general provisions of the standards of performance to allow methods other than Reference Method 9 to be used as a means of measuring plume opacity. The Environmental Protection Agency (EPA) is investigating a remote sensing laser radar system of measuring plume opacity and believes it could be considered as an alternative method to Reference Method

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9. This amendment would allow EPA to propose such systems as alternative methods in the future.

EFFECTIVE DATE: June 22, 1977.

FOR FURTHER INFORMATION CONTACT:

Don R. Goodwin, Emission Standards and Engineering Division, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, telephone no. 919-688-8146, ext. 271.

SUPPLEMENTARY INFORMATION: As originally expressed, 40 CFR 60.11(b) permitted the use of Reference Method 9 exclusively for determining whether a source complied with an applicable opacity standard. By this action, EPA amends § 60.11(b) so that alternative methods approved by the Administrator may be used to determine opacity.

When § 60.11(b) was originally promulgated, the visible emissions (Method 9) technique of determining plume opacity with trained visible emission observers was the only expedient and accurate method available to enforcement personnel. Recently, EPA funded the development of a remote sensing laser radar system (LIDAR) that appears to produce results adequate for determination of compliance with opacity standards. EPA is currently evaluating the equipment and is considering proposing its use as an alternative technique of measuring plume opacity.

This amendment will allow EPA to consider use of the LIDAR method of determining plume opacity and, if appropriate, to approve this method for enforcement of opacity regulations. If this method appears to be a suitable alternative to Method 9, it will be proposed in the FEDERAL REGISTER for public comment. After considering comments, EPA will determine if the new method will be an acceptable means of determining opacity compliance.

(Secs. 111, 114, 301(a), Clean Air Act, sec. 4(a) of Pub. L. 91-604, 84 Stat. 1683; sec. 4(a) of Pub. L. 91-604, 84 Stat. 1687; sec. 2 of Pub. L. No. 90-148, 81 Stat. 504 (42 U.S.C. 1857c-6, 1857c-9 and 1857g(a)).)

NOTE.—Economic Impact Analysis: The Environmental Protection Agency has determined that this action does not contain a major proposal requiring preparation of an Economic Impact Analysis under Executive Orders 11821 and 11949 and OMB Circular A-107.

Dated: May 10, 1977.

DOUGLAS M. COSTLE,
Administrator.

Part 60 of Chapter I, Title 40 of the Code of Federal Regulations is amended as follows:

1. Section 60.11 is amended by revising paragraph (b) as follows:

§ 60.11 Compliance with standards and maintenance requirements.

* * * * *

(b) Compliance with opacity standards in this part shall be determined by conducting observations in accordance with Reference Method 9 in Appendix A of this part or any alternative method that is approved by the Administrator. Opacity readings of portions of plumes which contain condensed, uncombined water vapor shall not be used for purposes of determining compliance with opacity standards. The results of continuous monitoring by transmissometer which indicate that the opacity at the time visual observations were made was not in excess of the standard are probative but not conclusive evidence of the actual opacity of an emission, provided that the source shall meet the burden of proving that the instrument used meets (at the time of the alleged violation) Performance Specification 1 in Appendix B of this part, has been properly maintained and (at the time of the alleged violation) calibrated, and that the resulting data have not been tampered with in any way.

* * * * *

(Secs. 111, 114, 301(a), Clean Air Act, Sec. 4(a) of Pub. L. 91-604, 84 Stat. 1683; sec. 4(a) of Pub. L. 91-604, 84 Stat. 1687; sec. 2 of Pub. L. No. 90-148 81 Stat. 504 (42 U.S.C. 1857c-6, 1857c-9, 1857g(a)).)

[FR Doc.77-14562 Filed 5-20-77;8:45 am]

Title 45—Public Welfare

CHAPTER I—OFFICE OF EDUCATION, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

PART 146—MODERN FOREIGN LANGUAGE AND AREA STUDIES

Awards of Grants and Contracts

AGENCY: Office of Education, HEW.

ACTION: Final regulation.

SUMMARY: These proposed regulations set forth rules and criteria governing the award of grants and contracts to institutions of higher education, qualified organizations and individuals for the purpose of providing Federal financial assistance to establish and operate Language and Area Studies Centers, Graduate and Undergraduate International Studies Programs, for the award of fellowships to individuals undergoing training in any center or under any program receiving Federal financial assistance under the NDEA Act, and for research and studies.

EFFECTIVE DATE: Pursuant to section 431(d) of the General Education Provisions Act, as amended (20 U.S.C. 1232 (d)), this regulation has been transmitted to the Congress concurrently with its publication in the FEDERAL REGISTER. That section provides that regulations subject thereto shall become effective on the forty-fifth day following the date of such transmission, subject to the provisions therein concerning Congressional action and adjournment.

DATES: None.

ADDRESSES: None.

FOR FURTHER INFORMATION CONTACT:

Edward L. Meador, Division of International Education, 7th and D Streets, SW., Room 3907, Regional Office Building #3, Washington, D.C. 20202 (202/245-9691)

SUPPLEMENTARY INFORMATION: The National Defense Education Act of 1958 in its statement of findings and declaration of policy says, "The Congress finds and declares that the security of the Nation requires the fullest development of the mental resources and technical skills of its young men and women. The present emergency demands that additional and more adequate educational opportunities be made available. The defense of this Nation depends upon the mastery of modern techniques developed from complex scientific principles. It depends as well upon the discovery and development of new principles, new techniques, and new knowledge."

(20 U.S.C. 401.)

The importance of a knowledge of foreign languages and area studies to the attainment of this policy was recognized by the inclusion in the Act of Title VI—Modern Foreign Language and Area Studies. This Title authorizes: Federal financial assistance to institutions of higher education for the establishment and operation of International Studies Centers and for Graduate and Undergraduate International Studies Programs, fellowships for graduate students in foreign language and area studies, and Federal financial assistance to public and private agencies, organizations and institutions as well as individuals for research in the area of foreign language and area studies.

"The International Studies Centers Program" provides grants to higher education institutions or consortia of such institutions to establish and operate centers focusing on one world region. These centers offer instruction in two or more of the area's principal languages and in other disciplines in order to provide training in understanding that particular world area. Other centers that feature instruction in comparative approaches to topics of concern to more than one nation, international relations, or interregional studies are also eligible for support. Awards are available in each category to centers having a combination of graduate and undergraduate instruction (unless undergraduate instruction is not offered) as well as to those offering only undergraduate training.

"The Graduate and Undergraduate International Studies Programs" may provide grants of up to two years, or in certain instances 3 years, to higher education institutions or consortia of such institutions to establish instructional programs in international studies at the graduate or undergraduate levels. Programs must be global or multi-area in instructional coverage. "Graduate Inter-

APPENDIX B

Omega-1 Lidar: Computer Software

(a) Lidar Computer Program (HP Language)

(b) Omega-5 Lidar Data Analysis Program (FORTRAN-4+)

(c) Omega-6 Lidar Data Output File Editor Program (FORTRAN-4+)

(d;1) Omega-7 Lidar Data Output Program for Tabular Data and Graphic Plots (FORTRAN-4+), Average Form

(d;2) Omega-8 Lidar Data Output Program for Tabular Data and Graphic Plots (FORTRAN-4+), Aggregate Form

(e) Lidar Eyesafe Program (FORTRAN-4+, HP Language and Variable Dictionary)

(f) FAA Report Program (HP Language)

B(a) Lidar Computer Program (HP Language)

```
0: "Omega 6/1,
 Lidar Operation
  Program, rev
 062981":
1: "start":fmt
 1,f5.0," to ",
 f5.0,"ns"
2: fmt 2,"gate",
 f2.0," at",f5.1
 ,"dB"
3: fmt 4,f5.0,
 f6.1,f5.1
4: fmt 5,f5.0,
 "ns for ",4c
5: fmt 6,x,f5.0,
 3x,f6.1
6: fmt 7,c,z
7: fmt 8,b,x,b,
 x,b,x,c19,x,b,
 x,b,x,b
8: fmt 9,c2,"/",
 c2,"/",c2,"
 file",/,c2,":",
 c2,":",c2,f5.0
9: wtc 15,277;
 wtc 15,144;wtb
 15,2048,2305;
 sfg 12
10: clr 7;fxd 0;
 188→r10;if flg7
 ;stp
11: sfg 7;dsp
 "REMOVE PROGRAM
  TAPE";0→r8;
 stp
12: "ent":cll
 'la'(73,6,130,
 19,2);jmp 'ea'(
 32)
13: A$→D$[53,84]
14: cll 'la'(125
 ,24,2);jmp 'ea'
 (32)
15: A$→D$[85,
 116]
16: "amp":cll
 'la'(150,17,2);
 jmp 'ea'(9)
17: cfg 11;if
 cap(A$[1,2])="L
 I";"0"→D$[25,
 25];jmp 4
```

```
18: if cap(A$[1,
 2])="LO";"1"→D$
 [25,25];sfg 11;
 sfg 12;jmp 3
19: if cap(A$[1,
 1])="T";"2"→D$[
 25,25];jmp 2
20: jmp -4
21: if flg11;
 "1"→D$[27,27];
 jmp 3
22: cll 'la'(95,
 10,185,13,2);
 str(drnd(log('e
 v'(3))/.33,1)+
 4)→A$
23: A$[2,2]→D$[2
 7,27]
24: cll 'la'(95,
 10,168,16,2)
25: str(drnd(log
 ('ev'(3))/.3398
 ,1))→A$
26: A$[2,2]→D$[2
 6,26];cll 'idpr
 3';D$[1,116]→E$
 ;sfg 0;gto "sta
 rt"
27: "idpr3":cll
 'rdck'
28: "idpr2":C→Y;
 D→Z;jmp 2
29: "idpr1":E→Y;
 F→Z
30: "idpr4":for
 L=1 to 16;char(
 31)→A$[L];next
 L;prt A$
31: cll 'headr'(
 Y,Z);prt D$[53,
 116]
32: fxd 2;prt "+
 or-"&str(drnd(t
 n↑((val(D$[27,
 27])-4).33),
 1))&" volts";
 fxd 0
33: prt str(drnd
 (tn↑(val(D$[26,
 26])*.3398),
 1))&"ns/pt"
34: jmp val(D$[2
 5,25])+1
35: "Linear"→A$;
 jmp 3
```

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```
36: "Log"→A$;
 jmp 2
37: "T"&char(29)
 →A$
38: cll 'p'('aa'
 (157,10,2));
 cll 'la'(54,11,
 2);A$&"at"→A$;
 cll 'p'
39: prt "9track
 file "&D$[17,
 20]
40: cll 'gprt'(1
 );cll 'gprt'(2)
41: fmt "AZ",
 f6.1,"EL",f5.1;
 wrt 16,r13,r14;
 fmt
42: for L=1 to
 16;char(0)→A$[L
 ];next L;prt A$
43: spc 2;ret
44: "lis":cmf 1;
 if not 'd'('la'
 (1,5,flg1));
 stp
45: wait 1500;
 cll 'la'(12,24,
 2);prnd('ev'(5)
 ,1)→A
46: cll 'la'(7,
 5,18,18,2);prnd
 ('ev'(5),1)→B;
 stp
47: "cal":cmf 2;
 cll 'd'('la'(37
 ,10,flg2));stp
48: "rec":cmf 3;
 if not 'd'('la'
 (65,7,flg3));
 stp
49: wait 1500;
 0→C;cll 'la'(73
 ,10,2);'en'(4)→
 D;cll 'position
 '(D)
50: E$[1,116]→D$
 [1,116];sfg 0;
 stp
51: "sou":cmf 4;
 if not flg4;
 jmp 3
52: cll 'd'('la'
 (84,20,2));wait
  1500
```

```
53: "soul":cll
 'la'(110,14,2);
 'en'(4)→N;stp
54: cll 'd'('la'
 (84,11,105,4,
 2));wait 1500;
 0→E;cfg 0
55: cll 'la'(73,
 10,2);'en'(4)→F
 ;cll 'position'
 (F);gto "soul"
56: "ref":cmf 6;
 jmp flg6+1
57: cll 'd'('la'
 (48,5,109,14,
 2));stp
58: cll 'd'('la'
 (54,10,109,14,
 2));stp
59: "reference":
 cmf 10;if not
 flg10;dsp "Refe
 rence used";
 sfg 0;stp
60: dsp "No refe
 rence";for I=1
 to 2;for J=1
 to 3
61: 0→P[I+1,J]→O
 [I,J];next J;
 next I;cfg 0;
 stp
62: "ran":cll
 'd'('la'(199,6,
 246,11,2));wait
  1000
63: cll 'la'(258
 ,24,2);prnd('ev
 '(5),1)→P[1,2]
64: cll 'la'(258
 ,9,283,4,272,
 10,2);prnd('ev'
 (5),1)→P[1,3];
 sfg 0;stp
65: "gat":cll
 'la'(199,29,2);
 if not 'ey';
 gto "gtst"
66: 9→G[1];9999→
 G[2]
67: cll 'la'(228
 ,17,2);'eg'(1,
 2)→Q
```

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```
68: cll 'la'(11,
 16,2);'eg'(1,
 5)→R
69: cll 'la'(6,
 6,18,9,2);'eg'(
 1,5)→S
70: cll 'la'(228
 ,17,2);'eg'(2,
 2)→T
71: cll 'la'(11,
 16,2);'eg'(2,
 5)→U
72: cll 'la'(6,
 6,18,9,2);'eg'(
 2,5)→V
73: cll 'code';
 stp
74: "gtst":stp
75: "t-square":c
 mf 5;if flg5;
 dsp "t-squared
 correction supp
 ressed";stp
76: dsp "t-squar
 ed correction
 allowed";stp
77: "lsopt":prt
 "OPTIONS SELECT
 ED"
78: for I=1 to
 16;"*"→A$[I];
 next I;prt A$;
 spc
79: if 'p'('la'(
 1,5,flg1));wrt
 16.1,A,B
80: spc ;cll
 'p'('la'(37,10,
 flg2))
81: spc ;if not
 'p'('la'(65,7,
 flg3));jmp 2
82: prt "9trk
 file"&str(D)
83: spc ;cll
 'la'(84,11,2)
84: if flg4;cll
 'p'('la'(95,9,
 2));jmp 2
85: cll 'p';prt
 "9trk file"&str
 (F)
86: prt str(N);
 cll 'p'('la'(11
 0,14,2));spc
```

```
87: if flg6;cll
 'p'('la'(54,10,
 2));cll 'p'('la
 '(109,14,2));
 jmp 2
88: cll 'p'('la'
 (48,5,2));cll
 'p'('la'(109,
 14,2))
89: spc 1;cll
 'gpr';cll 'rapr
 ';spc 2;stp
90: "fil":if
 'botst';1→r1;
 gto "fil1"
91: wrt 70201,
 "SF 2,1"
92: if not bit(4
 ,rds(70201));
 jmp 0
93: if 'botst';
 2→r1;wrt 70201,
 "SF1";gto "fil1
 "

94: wrt 70201,
 "SF1";cll 'read
 9'
95: val(D$[13,
 17])+1→r1;if
 flg0;E$[1,116]→
 D$[1,116]
96: "fil1":prt
 "9trk file"&str
 (r1);stp
97: "lsfil":cll
 'la'(73,10,2);
 'en'(4)→r1
98: cll 'la'(110
 ,14,2);'en'(4)+
 r1-1→r2
99: cll 'positio
 n'(r1)
100: for J=r1
 to r2;cll 'read
 9'(J);J→F;cll
 'decode';cll
 'idpr1'
101: next J;spc
 2;if flg0;E$[1,
 116]→D$[1,116]
102: stp
103: "clk":cll
 'd'('la'(287,
 26,2));wait
 1500
```

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```
104: cll 'la'(31
 4,12,495,8,2);
 cll 'aa'(475,4,
 322,2,2);jmp
 'ea'(10)
105: A$→D$[3,
 12];wtb 716,"R"
106: for I=323
 to 319 by -2
107: for J=1 to
 val(D$[I-312,I-
 311]);wtb 716,
 V$[I,I];next J
108: next I
109: val(D$[3,
 4])→r0;0→r2
110: if not (frc
 (23233232303/
 tn↑(r0-1))→r1);
 jmp 2
111: 10*r1→r1;
 int(r1)+r2→r2;
 if frc(r1)→r1;
 jmp 0
112: 28(r0-1)+
 r2+val(D$[5,
 6])→r2
113: if not frc(
 val(D$[1,2])/
 4);if r2>60;r2+
 1→r2
114: for I=2 to
 r2;wtb 716,"D";
 next I
115: fxd 2;stp
116: "go2":sfg 8
117: "go":if
 flg3;C→Y;D→Z;
 if D+N>1880;
 gto "tperr2"
118: if not flg3
  and flg4;9999→
 Z;jmp 2
119: if not flg3
  and not flg4;
 E→Y;F→Z;if F+
 N>1880;gto "tpe
 rr1"
120: if not flg4
  or not flg12;
 gto +3
```

```
121: if flg11;
 wtb 15,2104,
 4129,4505,4625,
 5632;cfg 12;
 gto +2
122: wtb 15,2056
 ;cfg 12
123: for I=1 to
 N
124: if not flg4
 ;jmp 3
125: cll 'bi';
 cll 'code';if
 flg3;C→Y;D→Z
126: gto +2
127: F→Z;cll
 'read9'(F);F+
 1→F;cll 'decode
 ';if flg6;F-
 1→H;jmp 5
128: if flg6
 and flg3;C→G;
 D→H;jmp 2
129: if flg6
 and not flg3
 and flg4;9999→H
130: if flg3
 and flg4;cll
 'record9'
131: if flg3
 and flg4;cll
 'headr'(C,D-1);
 gto +2
132: cll 'headr'
 (Y,Z)
133: if flg6;
 D$→R$
134: cll 'calcul
 ate';cll 'list'
 ;next I
135: if flg3
 and flg4;cll
 'endfile'
136: if not flg4
 ;stp
137: wtb 15,2560
138: if not bit(
 "xx00xxxx",rdb(
 15));jmp 0
139: cll 'rdck';
 gto -1
140: "tperr1":"R
 EAD"→A$;jmp 2
141: "tperr2":"R
 ECORDED"→A$
```

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```
142: prt "FILE
 # >1880","TO
 BE"&A$;spc 2;
 161→r1
143: wrt .8,r1,
 r1,r1,"   ERROR
    ",r1,r1,r1;
 stp
144: "bi":buf
 "data"
145: if flg8;
 wtb 15,3584,
 3586,2560;gto +
 2
146: wtb 15,2320
 ,3586,2560
147: 161→r1;wrt
 .8,r1,r1,r1,
 "FIRE PHOTON
 TORPEDO",r1,r1,
 r1
148: if not bit(
 "0110xxxx",rdb(
 15));jmp 0
149: if not flg8
 ;cll 'rdck'
150: cll 'angle'
151: wtb "data",
 D$[1,116];wtb
 15,2816
152: tfr 15,"dat
 a",2048
153: wtb 15,3584
 ;if flg8;wtb
 15,2320;cfg 8
154: beep;dsp
 "WAIT";ret
155: "angle":0→r
 14;wrt 706.7,
 "H11BJ"
156: for J=1 to
 10;r14+rot(rdb(
 706),8)+rdb(706
 )→r14;next J
157: 0→r13;wrt
 706.7,"H22BJ"
158: for J=1 to
 10;r13+rot(rdb(
 706),8)+rdb(706
 )→r13;next J
159: wrt 706.7,
 "H"
160: r14/11.1111
 111→r14;r13/
 11.1111111→r13
```

```
161: "0000000"→D
 $[46,52];str(ab
 s(r13-r8))→A$;
 A$[2]→D$[49,49]
162: if abs(r13-
 r8)>9;A$[2]→D$[
 48,49]
163: if abs(r13-
 r8)>99;A$[2]→D$
 [47,49]
164: if abs(r13-
 r8)>999;A$[2]→D
 $[46,49]
165: if r13-r8<0
 ;char(num(D$[46
 ])+64)→D$[46,
 46]
166: str(abs(r14
 ))→A$;A$[2]→D$[
 52,52]
167: if abs(r14)
 >9;A$[2]→D$[51,
 52]
168: if abs(r14)
 >99;A$[2]→D$[50
 ,52]
169: if r14<0;
 char(num(D$[50]
 )+64)→D$[50,50]
170: ret
171: "rdck":fmt
 ;red 716,A$;
 A$[3,12]→D$[3,
 12];ret
172: "code":cll
 'cod'(Q*10,34);
 cll 'cod'(R,
 28);cll 'cod'(S
 ,31)
173: cll 'cod'(T
 *10,43);cll
 'cod'(U,37);
 cll 'cod'(V,
 40);ret
174: "cod":p2+
 2→p3;p1→p4
175: char(frc(in
 t(p4)/100→p4)*
 100)→D$[p3,p3];
 if (p3-1→p3)>=p
 2;jmp 0
176: ret
177: "decode":'d
 ec'(34)/10→Q;
 'dec'(28)→R;
 'dec'(31)→S
```

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```
178: 'dec'(43)/
 10→T;'dec'(37)→
 U;'dec'(40)→V;
 ret
179: "dec":p1+
 3→p2
180: p3*100+num(
 D$[p1,p1])→p3;
 if (p1+1→p1)#p2
 ;jmp 0
181: ret p3
182: "calculate"
 :if flg6;2→r0;
 gto "calc1"
183: 3→r0;if
 not flg2;ret
184: if flg0
 and not flg10;
 2→r0;gto +3
185: if flg10;
 prt " time  *
 "&char(2)&"
 "&char(9);jmp 2
186: "calc1":prt
  " time   "&cha
 r(2)&"    "&cha
 r(9)
187: sfg 14;drnd
 (tn↑(val(D$[26,
 26]).3398),1)→p
 1;'w'(3-r0)→W
188: for J=2 to
 3;P[1,J]/p1+
 117→p4;0→p2→p3
189: for K=p4
 to p4+9
190: 'dat'(K,W,
 3-r0)→p5
191: p2+p5→p2;
 p3+p5↑2→p3
192: next K;p2/
 10→P[r0,J];√abs
 (p3/9-p2↑2/90)→
 O[r0-1,J]
193: if flg6 or
 not flg0 or
 flg10;wrt 16.4,
 P[1,J],P[r0,J],
 O[r0-1,J]
194: next J
195: if not flg6
 ;jmp 3
```

```
196: if flg10;
 for I=1 to 2;
 for J=1 to 3;
 0→P[I+1,J]→O[I,
 J];next J;next
 I
197: spc 2;cfg
 0,6,14,15;ret
198: if flg0
 and not flg10;
 cfg 0;gto "calc
 ulate"
199: fxd 0;prt
 "%Op=  "&str('e
 val')&"   "&str
 ('dif')
200: if max(O[*
 ])>20;sfg 15
201: if not flg4
  and not flg6;
 if val(D$[17,
 20])#H;prt "WRO
 NG REF"
202: if not flg1
 5;gto +2
203: prt "  "&ch
 ar(94)&" in
 error???"
204: cfg 6,14,
 15;spc 2;ret
205: "w":if flg9
 ;ret 1
206: 1/drnd(tn↑(
 val(D$[26,26]).
 3398),1)→r7
207: 0→r3;for
 J=117 to 126;
 if p1=0;r3+eor(
 128,num(D$[J]))
 →r3;jmp 2
208: r3+eor(128,
 num(R$[J]))→r3
209: next J;r3/
 10→r3
210: 'dat'(r7P[1
 ,2]+117,1,p1)→p
 2
211: ret 80/p2
212: "dat":if
 p3=0;eor(128,
 num(D$[p1]))→p4
 ;jmp 2
213: eor(128,
 num(R$[p1]))→p4
```

```
214: if flg9;
 ret p4
215: p4-r3→p4
216: if p3;if
 R$[25,25]="1";
 (8e-7)1.046↑p4→
 p4;jmp 2
217: if D$[25,
 25]="1";(8e-
 7)1.046↑p4→p4
218: if flg5;
 gto +3
219: if p3;if
 R$[25,25]#"2";
 if p1>72;p4(p1-
 r10)↑2→p4;jmp 2
220: if D$[25,
 25]#"2";if p1>7
 2;p4(p1-191)↑2→
 p4
221: if p1>=R
 and p1<=S;p4/
 tn↑(Q/10)→p4
222: if p1>=U
 and p1<=V;p4/
 tn↑(T/10)→p4
223: ret p2p4
224: "eval":P[2,
 2]+1e-20→A[1];
 P[2,3]+1e-20→A[
 2]
225: P[3,2]→A[3]
 ;P[3,3]→A[4]
226: ret 100(1-
 √(A[4]A[1]/A[2]
 A[3]))
227: "dif":P[2,
 2]+1e-20→p1;
 P[2,3]+1e-20→p2
 ;P[3,2]+1e-20→p
 3;P[3,3]+1e-
 20→p4
228: O[1,2]→p5;
 O[1,3]→p6;O[2,
 2]→p7;O[2,3]→p8
229: 50√((p1p4/
 p2p3)(p5p5/p1p1
 +p6p6/p2p2+p7p7
 /p3p3+p8p8/p4p4
 ))→p9;ret p9
230: "list":if
 not flg1;ret
231: drnd(tn↑(va
 l(D$[26,26]).33
 98),1)→r0
232: 'w'(0)→W
```

```
233: prt "9trk
 file"&str(Z);
 spc 1;prt "time
 (ns) value"
234: for J=A/r0+
 117 to B/r0+117
235: 'dat'(J,W,
 0)→r2;r0(J-117)
 →r1
236: wrt 16.6,
 r1,r2;next J;
 spc 2;ret
237: "headr":wrt
  16.9,D$[3,4],
 D$[5,6],D$[1,
 2],D$[7,8],D$[9
 ,10],D$[11,12],
 p2
238: fmt "AZ",
 f6.1,"EL",f5.1;
 wrt 16,r13/10,
 r14/10
239: ret
240: "gpr":if
 'gprt'(1);spc
241: if 'gprt'(2
 );spc
242: ret
243: "gprt":if
 p1=1;if Q;wrt
 16.2,p1,Q;wrt
 16.1,R,S;ret 1
244: if T;wrt
 16.2,p1,T;wrt
 16.1,U,V;ret 1
245: ret 0
246: "rapr":if
 not P[1,2];ret
247: prt "Pickin
 g at";wrt 16.5,
 P[1,2],"near";
 wrt 16.5,P[1,
 3],"far";ret
248: "p":prt
 A$[1,16];ret p1
249: "d":dsp
 A$[1,32];ret p1
250: "aa":A$&V$[
 p1,p1+p2-1]→A$;
 jmp 2
251: "la":V$[p1,
 p1+p2-1]→A$
252: if p0=3;
 p3→p7;jmp 3
```

```
253: A$&V$[p3,
 p3+p4-1]→A$;if
 p0=5;p5→p7;jmp
 2
254: A$&V$[p5,
 p5+p6-1]→A$
255: jmp p7+1
256: A$&" OFF"→A
 $;jmp 3
257: A$&" ON"→A$
 ;jmp 2
258: A$&""→A$
259: ret p7
260: "e":fxd 0;
 dsp "Enter "&A$
 ;ent "",A$;ret
261: "ea":cll
 'e';if len(A$)<
 =p1;ret 1
262: beep;dsp
 "enter "&str(p1
 )&" characters
 only!";wait
 1500;ret 0
263: "en":"# of
 "&A$→A$;cll
 'e';A$[1,p1]→A$
 ;ret abs(val(A$
 ))
264: "ev":cll
 'e';A$[1,p1]→A$
 ;ret abs(val(A$
 ))
265: "ey":dsp
 A$;ent "",A$;
 if cap(A$)="NO"
 ;ret 0
266: if cap(A$)=
 "YES";ret 1
267: "yes or
 no?"→A$;jmp -2
268: "eg":"gate
 "&str(p1)&A$→A$
 ;prnd('ev'(5),
 p2-3)→p1;ret p1
269: "t0":1/drnd
 (tn↑(val(D$[26,
 26]).3398),1)→r
 7;r13→r8;r14→r9
270: for I=146
 to 316;if eor(1
 28,num(D$[I]))>
 =250;jmp 3
271: next I
```

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```
272: 167+int(210
 r7)→r10;dsp
 "T0 not found.
 Set to 710 ns."
 ;stp
273: if eor(128,
 num(D$[I-1]))>=
 eor(128,num(D$[
 I]));jmp 2
274: I-1→I;jmp -
 1
275: I+1→r10;
 ent "stack sear
 ch start time:"
 ,r11;int(r7r11)
 +117→r11
276: for I=r11
 to 2117;if eor(
 128,num(D$[I]))
 >=250;jmp 3
277: next I
278: dsp "Stack
 not found.";
 stp
279: if eor(128,
 num(D$[I-1]))>=
 eor(128,num(D$[
 I]));jmp 2
280: I-1→I;jmp -
 1
281: (I-116)/
 r7→r11;.1498962
 26(I+1-r10)/
 r7→r12
282: prt "T0
 is",(r10-117)/
 r7;prt "Stack
 is",r11;prt
 "distance",r12;
 stp
283: "plot1":ent
  "Enter max
 time scale (ns)
 ",W
284: ent "Enter
 min plot time
 (ns)",r5
285: ent "Enter
 max plot time
 (ns)",X
286: ent "First
 file?",r2,"Last
  file?",r4
```

```
287: sfg 9;ent
 "Compensate?",
 A$;if cap(A$[1,
 1])="Y";cfg 9
288: deg;csiz
 1.05,1.5,.8,90;
 cll 'position'(
 r2)
289: for L=0 to
 94;scl -250,
 5250,-W/8,W
290: for I=20L
 to 20(L+1)-1
291: plt 250,-W/
 8.5,1
292: if r2+I>r4;
 stp
293: cll 'read9'
 (r2+I)
294: 'w'(0)→Q;
 lbl D$[7,8]&":"
 &D$[9,10]&":"&D
 $[11,12]
295: for K=r5/
 10 to X/10
296: 'dat'(K+
 117,Q,0)→r0
297: "plt3":if
 r0>255;255→r0
298: plt 250-r0,
 10K
299: next K;pen;
 ofs 250,0
300: next I;beep
 ;wait 2000;beep
 ;wait 2000;beep
 ;stp
301: next L;stp
302: "3d":wtb
 706,255
303: dsp "Open
 shutter, depres
 s cont.";stp
304: cll 'ask
 file'
305: ent "Enter
 number of files
 .",r18;if r18>2
 56;jmp 0
306: ent "Start
 sweep time at
 ? ns",r17;int(.
 1r17)→r17
307: for L=0 to
 r18-1
308: wtb 705,L
```

```
309: cll 'read9'
 (r16);r16+1→r16
 ;'w'(0)→W
310: for I=0 to
 255
311: wtb 704,I
312: wtb 706,
 .5(255-'dat'(I+
 117+r17,W,0))
313: next I
314: wtb 706,255
315: next L;stp
316: "ask file":
 dsp "Load 9-
 track tape,
 press cont.";
 stp
317: ent "Start
 at file?",r16;
 cll 'position'(
 r16);ret
318: "record9":"

 "→D$[13,24];
 fxd 0;cll 'filc
 ode'(G,H,17)
319: cll 'filcod
 e'(C,D,13);cll
 'filcode'(G[1],
 G[2],21)
320: fmt ;cll
 'wptst';if bit(
 4,rds(70201));
 gto +2
321: wait 100;
 if not bit(4,
 rds(70201));
 gto "err9"
322: wrt 70201,
 "ED 256,1082;
 CC0;WR 2"
323: tfr "data",
 70202,2164
324: wrt 70201,
 "WF";cll 'eotst
 ';D+1→D;ret
325: "position":
 fmt ;if bit(0,
 rds(70201));
 dsp V$[393,415]
 ;stp
326: if p1<10;
 gto "posi1"
327: wrt 70201,
 "SF 3,1"
```

```
328: if not bit(
 4,rds(70201));
 jmp 0
329: if 'botst';
 1→p2;gto "posi2
 "
330: wrt 70201,
 "SF 1";cll 'rea
 d9'
331: val(D$[13,
 17])+1→p2;if
 p1>=p2;gto "pos
 i2"
332: if 5p2>12p1
 ;gto "posi1"
333: fxd 0;"SF"→
 A$;A$&str(p2-
 p1+1)→A$;A$&",
 1;SF 1"→A$
334: wrt 70201,
 A$;ret
335: "posi1":wrt
  70201,"RW";
 1→p2
336: if not bit(
 4,rds(70201));
 jmp 0
337: "posi2":if
 p1<=p2;p2→p1;
 ret
338: for J=p2+1
 to p1;wrt 70201
 ,"SR 1"
339: if 'eoftst'
 (J);J→p1;stp
340: if 'eotst'(
 J);J-1→p1;stp
341: wrt 70201,
 "SF 1";if 'eots
 t'(J);J→p1;stp
342: next J;ret
343: "endfile":f
 mt ;wrt 70201,
 "WF;SF 2,1;SF
 1";if 'eotst'(p
 1);stp
344: ret
345: "read9":fmt
  ;wrt 70201,
 "SR1;SR1,1";if
 'eoftst'(p1);
 p1-1→p1;stp
346: if 'eotst'(
 p1);p1-1→p1;
 stp
```

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```
347: wrt 70201,
 "ED 256,1082,0;
 CC0;RR 2";buf
 "data"
348: tfr 70202,
 "data",1082
349: tfr 70202,
 "data",1082
350: cmd 7,"-";
 wrt 70201,"SF
 1";if 'eotst'(p
 1);stp
351: ret
352: "botst":fmt
  ;red 70201,p1,
 p2,p3,p4;if
 bit(3,p2);ret 1
353: ret 0
354: "wptst":fmt
  ;if bit(3,rds(
 70201));dsp
 V$[326,343];
 stp
355: ret
356: "eoftst":fm
 t ;if not bit(4
 ,rds(70201));
 jmp 0
357: fxd 0
358: if bit(1,
 rds(70201));
 dsp V$[345,371]
 &str(p1);wrt
 70201,"SF2,1;
 SF1";ret 1
359: ret 0
360: "eotst":fmt
  ;if not bit(4,
 rds(70201));
 jmp 0
361: fxd 0
362: if bit(2,
 rds(70201));
 dsp V$[373,391]
 &str(p1);wrt
 70201,"SF2,1;
 SF";ret 1
363: ret 0
364: "filcode":s
 tr(p2)→A$;A$[2]
 →D$[p3+3,p3+3];
 if p2>9;A$[2]→D
 $[p3+2,p3+3]
```

```
365: if p2>99;
 A$[2]→D$[p3+1,
 p3+3];if p2>999
 ;A$[2]→D$[p3,
 p3+3]
366: ret
367: "err9":dsp
 "9-TRACK ERROR!
 !!";stp
*2808
```

```
f0: *cont"amp"

f1: *cont"lis"

f2: *cont"cal"

f3: *cont"rec"

f4: *cont"sou"

f5: *→N

f6: *cont"ref"

f7: *cont"ent"

f8: *cont"lsopt"

f9: *cont"gat"

f10: *cont"ran"

f11: *cont"go"

f12: *cont"t0"

f13: *cont"go2"

f14: *cont"3d"

f15: *cont"refer
 ence"

f16: *→P[1,2];sf
 g0

f17: *→P[1,3];sf
 g0

f18: *cont"fil"

f19: *gsb"idpr3"

f20: *cont"lsfil
 "

f21: *cont"t-squ
 are"

f22: *cont"clk"

f23: *cont"start
 "
```

B(b) Omega-5 Lidar Data Analysis Program (FORTRAN-4+)

```
OMEGA-1 LIDAR.   OPACITY DATA ANALYSIS PROGRAM.   DESCRIPTION OF COMMANDS.

:A :AC  ACCEPT;  STORE THE LATEST CALCULATED OPACITY IN THE REPORT ARRAYS,
        AND ADD THE INFORMATION TO THE OUTPUT FILE IF ONE IS OPEN.

:AU     AUTO FLAG;  CHANGES THE STATE OF THE AUTO FLAG.  PICK POINTS ARE
        SELECTED AUTOMATICALLY OR MANUALLY DEPENDING ON THE STATE OF THE FLAG.

:AV     AVERAGE;  SPECIFY THE AVERAGING INTERVAL IN MINUTES.

:BA     BACK TO PLUME;  RESTART THE PICK POINT SEARCH AT THE PLUME.

:B :BE  BEGIN REPORT INTERVAL;  INITIALIZE REPORT COUNTERS.  IF AN OUTPUT FILE
        IS NOT OPEN, ONE MAY BE OPENED TO SAVE THE REPORT ARRAYS BEFORE THEY ARE
        LOST.  A NEW OUTPUT FILE MAY THEN BE SPECIFIED FOR FUTURE DATA.

:C :CO  COMP FLAG;  CHANGES THE STATE OF THE COMP FLAG.  DATA IS COMPENSATED
        OR NOT DEPENDING ON THE STATE OF THE FLAG.

:D :DA  DATA;  DATA SHOT WILL BE USED FOR DISPLAY, ID, AND LIST.

:DI     DISPLAY;  DISPLAY ON THE VT100 SCREEN THE REFERENCE SHOT OR DATA SHOT,
        WHICHEVER IS SELECTED.

:DX     DISPLAY-X;  SELECT THE X-RESOLUTION FOR THE DISPLAY.

:DY     DISPLAY-Y;  SELECT THE Y-RESOLUTION FOR THE DISPLAY.

:E :EN  END REPORT INTERVAL;  THE OUTPUT FILE IS CLOSED.  IF A FILE IS NOT OPEN,
        ONE MAY OPENED TO SAVE THE REPORT ARRAYS BEFORE THEY ARE MODIFIED.
        THE REPORT ARRAYS ARE THEN PURGED SO THAT ONLY THE VALUES NEEDED FOR
        THE LAST RUNNING AVERAGE ARE INCLUDED.  A NEW OUTPUT FILE MAY THEN BE
        SPECIFIED TO SAVE THE UPDATED ARRAYS AND ANY ADDITIONAL RESULTS.

:EX     EXIT;  CLOSE THE OUTPUT FILE, RESTORE THE VT100 TO ITS NORMAL STATE,
        AND EXIT THE PROGRAM.

:F :FA  FAR;  IN MANUAL MODE, SET THE FAR PICK POINT.
        IN AUTOMATIC MODE, MOVE THE FAR PICK POINT AWAY FROM THE PLUME TO THE
        NEXT RELATIVE MINIMUM.

:FI     FILE NUMBER;  SELECT THE "FILE" OR "SHOT" NUMBER OF THE NEXT SHOT TO BE
        READ FROM THE SOURCE FILE.

:H :HE  HELP;  PROVIDES ASSISTANCE FOR THE USER.

:ID     ID HEADER;  TYPE THE HEADER INFORMATION FOR THE REFERENCE OR DATA SHOT,
        WHICHEVER IS SELECTED.

:L :LI  LIST;  PRINT THE HEADER INFORMATION AND THE RAW LIDAR DATA FROM EITHER
        THE REFERENCE OR DATA SHOT, WHICHEVER IS SELECTED.

:N :NE  NEAR;  IN MANUAL MODE, SET THE NEAR PICK POINT.
        IN AUTOMATIC MODE, MOVE THE NEAR PICK POINT AWAY FROM THE PLUME TO THE
        NEXT RELATIVE MINIMUM.

:NO     NO REFERENCE;  A REFERENCE SHOT WILL NOT BE USED IN THE OPACITY
        CALCULATION.

:OF     OLD FILE;  TO SPECIFY AND READ IN A FILE CONTAINING RESULTS SO THAT
        MORE DATA MAY BE ADDED TO IT.

:O :OP  OPACITY;  CALCULATE AND DISPLAY OPACITY.
```

```
:OU      OUTPUT FILE;  SPECIFY A NEW OUTPUT FILE, OPEN IT, AND WRITE THE REPORT
         ARRAYS IN IT.  IF A FILE IS ALREADY OPEN, IT IS CLOSED.

:PK      PICK POINTS;  IN MANUAL MODE, SET BOTH PICK POINTS.
         IN AUTOMATIC MODE, MOVE BOTH PICK POINTS AWAY FROM THE PLUME TO THE
         NEXT RELATIVE MINIMA.

:P :PR   PRINT REPORT;  PRINT THE RESULTS IN THE REPORT ARRAYS ON THE LINE
         PRINTER IN SUMMARY FORM; AND, IF DESIRED, IN REPORT FORM.

:RC      RN, RF CALCULATE;  CALCULATE AND DISPLAY RN AND RF.

:R :RD   READ DATA;  READ A NEW DATA SHOT FROM THE SOURCE FILE.

:RE      REFERENCE;  REFERENCE (AMBIENT AIR) SHOT WILL BE USED FOR DISPLAY, ID,
         AND LIST.

:RR      READ REFERENCE;  READ A NEW REFERENCE SHOT FROM THE SOURCE FILE.

:RS      RESID FLAG;  CHANGES THE STATE OF THE RESID FLAG.  RESIDUAL PLUME
         CORRECTION TO THE OPACITY IS MADE OR NOT, DEPENDING ON THE STATE OF THE
         FLAG.

:S :SO   SOURCE;  TO SPECIFY AND OPEN A SOURCE FILE.

:ST      START;  TO INITIALIZE ALL PROGRAM VARIABLES AND FLAGS.

:SL      SEARCH LIMITS;  SET THE BOUNDS FOR THE AUTOMATIC PICK POINT SEARCH.

:TO      TIME REFERENCE;  SET TO, THE TIME THE LASER FIRES.  TO MAY BE SPECIFIED
         OR DETERMINED AUTOMATICALLY FROM A TO SHOT.

:T2      T2 FLAG;  CHANGES THE STATE OF THE T2 FLAG.  T-SQUARED CORRECTION IS
         EITHER PERMITTED OR SUPPRESSED, DEPENDING ON THE STATE OF THE FLAG.

:Y :YE   YES REFERENCE;  THE REFERENCE SHOT WILL BE USED IN OPACITY CALCULATIONS.
```

```
FORTRAN IV-PLUS V02-51E         10:37:50    04-MAY-81           PAGE 1
OMEG5A.FTN          /TR:BLOCKS/WR

0001                PROGRAM OMEGA5
            C       THIS PROGRAM IS USED TO ANALYZE OMEGA-1 LIDAR OPACITY DATA.
            C
            C       LIDAR SHOTS ARE DISPLAYED ON THE VT100 TERMINAL SCREEN AND
            C       OUTPUT DATA MAY BE PRINTED IN TABULAR FORM AND/OR
            C       SAVED FOR FUTURE USE.
            C
            C       THE PROGRAM IS ORGANIZED INTO SEVEN SEGMENTS: A ROOT SEGMENT CONTAINING
            C       PROGRAM CONTROL, ALL DATA, AND THE MOST COMMONLY USED SUBROUTINES, AND
            C       SIX MUTUALLY INDEPENDENT SEGMENTS WHICH SHARE THE SAME MEMORY.  SEE THE
            C       MEMORY MAP FOR DETAILS.
            C
            C       COMMANDS ARE GIVEN TO THE PROGRAM IN RESPONSE TO A COLON
            C       PROMPT(:).
            C
            C       AVAILABLE COMMANDS ARE:
            C
            C       :S :SO  SOURCE;  TO SPECIFY AND OPEN A SOURCE FILE.
            C       :OF     OLD FILE;  TO SPECIFY AND READ IN A FILE CONTAINING RESULTS
            C               SO THAT MORE DATA MAY BE ADDED TO IT.
            C       :ST     START;  TO INITIALIZE ALL PROGRAM VARIABLES AND FLAGS.
            C       :RE     REFERENCE;  REFERENCE (AMBIENT AIR) SHOT WILL BE USED FOR
            C               DISPLAY, ID, AND LIST.
            C       :D :DA  DATA;  DATA SHOT WILL BE USED FOR DISPLAY, ID AND LIST.
            C       :R :RD  READ DATA;  READ A NEW DATA SHOT FROM THE SOURCE FILE.
            C       :RR     READ REFERENCE;  READ A NEW REFERENCE SHOT FROM THE SOURCE FILE.
            C       :AU     AUTO FLAG;  CHANGES THE STATE OF THE AUTO FLAG.  PICK POINTS ARE
            C               SELECTED AUTOMATICALLY OR MANUALLY DEPENDING ON THE STATE OF THE
            C               FLAG.
            C       :SL     SEARCH LIMITS;  SET THE BOUNDS FOR THE AUTOMATIC PICK POINT
            C               SEARCH.
            C       :BA     BACK TO PLUME;  RESTART THE PICK POINT SEARCH AT THE PLUME.
            C       :N :NE  NEAR;  SET THE NEAR PICK POINT.
            C       :F :FA  FAR;  SET THE FAR PICK POINT.
            C       :PK     PICKS;  SET BOTH PICK POINTS.
            C       :FI     FILE;  SELECT THE "FILE" OR "SHOT" NUMBER OF THE NEXT SHOT
            C               TO BE READ FROM THE SOURCE FILE.
            C       :ID     ID;  TYPE THE HEADER INFORMATION FOR THE REFERENCE OR DATA
            C               SHOT, WHICHEVER IS SELECTED.
            C       :L :LI  LIST;  PRINT THE HEADER INFORMATION AND THE RAW LIDAR DATA
            C               FROM EITHER THE REFERENCE OR DATA SHOT, WHICHEVER IS SELECTED.
            C       :NO     NO REFERENCE;  A REFERENCE SHOT WILL NOT BE USED IN THE
            C               OPACITY CALCULATION.
            C       :Y :YE  YES REFERENCE;  THE REFERENCE SHOT WILL BE USED IN THE OPACITY
            C               CALCULATION.
            C       :T2     T2 FLAG;  CHANGES THE STATE OF THE T2 FLAG.  T-SQUARED
            C               CORRECTION IS EITHER PERMITTED OR SUPPRESSED, DEPENDING
            C               ON THE STATE OF THE FLAG.
            C       :C :CO  COMP FLAG;  CHANGES THE STATE OF THE COMP FLAG.  DATA IS
            C               COMPENSATED OR NOT DEPENDING ON THE STATE OF THE FLAG.
            C       :TO     TO;  SPECIFY A NEW TO VALUE. (DEFAULT 710 NANOSECONDS)
            C       :RS     RESID FLAG;  CHANGES THE STATE OF THE RESID FLAG.  RESIDUAL
            C               PLUME CORRECTION TO THE OPACITY IS MADE OR NOT DEPENDING ON
            C               THE STATE OF THE FLAG.
            C       :DI     DISPLAY;  DISPLAY ON THE VT100 SCREEN THE REFERENCE SHOT
            C               OR DATA SHOT, WHICHEVER IS SELECTED.
```

```
C       :DX     DISPLAY LIMITS;  SELECT THE X-RESOLUTION FOR THE DISPLAY.
C       :DY     DISPLAY LIMITS;  SELECT THE Y-RESOLUTION FOR THE DISPLAY.
C       :RC     RN, RF CALCULATE;  CALCULATE AND DISPLAY RN AND RF.
C       :O :OP  OPACITY;  CALCULATE AND DISPLAY OPACITY.
C       :OU     OUTPUT FILE;  SPECIFY THE NEW OUTPUT FILE, OPEN IT, AND WRITE
C               THE REPORT ARRAYS IN IT.  IF A FILE IS ALREADY OPEN, IT IS
C               CLOSED.
C       :B :BE  BEGIN REPORT INTERVAL;  INITIALIZE REPORT COUNTERS.  IF AN
C               OUTPUT FILE IS NOT OPEN, AN OUTPUT FILE MAY BE OPENED TO SAVE
C               THE OLD DATA FROM THE REPORT ARRAYS BEFORE IT IS LOST.
C               A NEW OUTPUT FILE NAME IS THEN REQUESTED, AND IF PROVIDED,
C               THE FILE IS OPENED.
C       :E :EN  END REPORT INTERVAL;  THE OUTPUT FILE IS CLOSED.  IF A FILE
C               IS NOT OPEN, ONE MAY BE OPENED TO SAVE THE REPORT ARRAYS BEFORE
C               THEY ARE MODIFIED.  THE REPORT ARRAYS ARE THEN COMPRESSED
C               SO THAT ONLY THE VALUES INCLUDED IN THE LAST RUNNING AVERAGE
C               ARE INCLUDED.  A NEW OUTPUT FILE NAME IS REQUESTED.  IF ONE IS
C               PROVIDED, THE FILE IS OPENED AND THE CURRENT REPORT ARRAYS ARE
C               WRITTEN IN IT.
C       :AV     AVERAGE;  SPECIFY THE AVERAGING INTERVAL IN MINUTES.
C       :A :AC  ACCEPT;  STORE THE LATEST CALCULATED OPACITY IN THE REPORT
C               ARRAYS, AND ADD THE INFORMATION TO THE OUTPUT FILE.
C       :P :PR  PRINT;  PRINT THE RESULTS IN THE REPORT ARRAYS ON THE LINE
C               PRINTER IN SUMMARY FORM, AND IF DESIRED IN REPORT FORM.
C       :EX     EXIT;  EXIT THE PROGRAM AND RESTORE THE VT100 TO ITS NORMAL
C               STATE.
C       :WD     SET THE TERMINAL TO DISPLAY 132 CHARACTER LINES.
C
C       FOLLOWING ARE THE DEFINITIONS OF THE ARRAYS, FLAGS, AND VARIABLES
C       USED IN THE PROGRAM.
C
C       IAUX(52,3)      THIS ARRAY STORES THE HEADER INFORMATION FOR EACH LIDAR
C                       SHOT.  THE SECOND INDEX INDICATES WHICH SHOT: 1 IS THE
C                       DATA SHOT, 2 IS THE REFERENCE SHOT, AND 3 IS USED
C                       INTERNALLY BY THE PROGRAM FOR SEARCHING WITHOUT
C                       DISTURBING THE DATA OR REFERENCE.  THE INFORMATION
C                       STORED IN EACH ELEMENT IS DEFINED AS FOLLOWS:
C
C               1       MONTH
C               2       DAY
C               3       YEAR
C               4       HOUR
C               5       MINUTE
C               6       SECOND
C               7       CURRENT FILE NUMBER
C               8       REFERENCE SHOT FILE NUMBER
C               9       GATE CALIBRATION SHOT FILE NUMBER
C               10      AMPLIFIER TYPE: LO, LI, T2
C               11      SAMPLE INTERVAL IN NANOSECONDS
C               12      VOLTAGE RANGE IN MILLIVOLTS
C               13      GATE 1 START TIME IN NANOSECONDS
C               14      GATE 1 STOP TIME IN NANOSECONDS
C               15      GATE 1 ATTENUATION IN TENTHS OF A DB
C               16      GATE 2 START TIME IN NANOSECONDS
C               17      GATE 2 STOP TIME IN NANOSECONDS
C               18      GATE 2 ATTENUATION IN TENTHS OF A DB
```

```
      C                19      AZIMUTH ANGLE IN TENTHS OF A DEGREE
      C                20      ELEVATION ANGLE IN TENTHS OF A DEGREE
      C                21-52   64 CHARACTERS OF ID INFORMATION
      C
      C         IDAT(2048,2)   LIDAR DATA.  THE SECOND INDEX INDICATES WHICH SHOT
      C                        1 FOR DATA AND 2 FOR REFERENCE OR AMBIENT.
      C
      C         REP(14,136)    THESE TWO ARRAYS ARE THE REPORT ARRAYS.  FOR EACH
      C         IREP(12,136)   CALCULATED OPACITY 14 FLOATING POINT NUMBERS AND
      C                        12 INTEGERS ARE STORED.  INFORMATION FROM 136 SHOTS
      C                        CAN BE RECORDED.  THE FLOATING POINT NUMBERS ARE STORED
      C                        IN REP(14,I) AS DEFINED BELOW
      C
      C                1       DATA AT NEAR PICK POINT
      C                2       STANDARD DEVIATION OF DATA AT NEAR PICK POINT
      C                3       REFERENCE AT NEAR PICK POINT
      C                4       STANDARD DEVIATION OF REFERENCE AT NEAR PICK POINT
      C                5       DATA AT FAR PICK POINT
      C                6       STANDARD DEVIATION OF DATA AT FAR PICK POINT
      C                7       REFERENCE AT FAR PICK POINT
      C                8       STANDARD DEVIATION OF REFERENCE AT FAR PICK POINT
      C                9       OPACITY NOT CORRECTED FOR ANGLE
      C                10      OPACITY CORRECTED FOR AZIMUTH AND ELEVATION ANGLE
      C                11      SO, (STANDARD DEVIATION OF OPACITY)
      C                12      RUNNING AVERAGE OF OPACITY
      C                13      RUNNING AVERAGE OF SO
      C                14      MINUTES IN CURRENT RUNNING AVERAGE
      C
      C                        THE INTEGERS ARE STORED IN IREP(12,I) AS FOLLOWS:
      C
      C                1       MONTH
      C                2       DAY
      C                3       YEAR
      C                4       HOUR
      C                5       MINUTE
      C                6       SECOND
      C                7       FILE NUMBER
      C                8       REFERENCE FILE NUMBER
      C                9       NEAR PICK TIME IN NANOSECONDS
      C                10      FAR PICK TIME IN NANOSECONDS
      C                11      NUMBER OF OPACITIES IN CURRENT RUNNING AVERAGE
      C                12      NUMBER OF SO'S IN CURRENT RUNNING AVERAGE
      C
      C         IOFILE(9)      OUTPUT FILE SPECIFICATION
      C         ISFILE(9)      SOURCE FILE SPECIFICATION
      C         IRFILE(9)      SAVE FILE SPECIFICATION
      C         IDISP(132,2)   DISPLAY ARRAY.  THIS ARRAY STORES DATA IN FINAL FORM
      C                        FOR OUTPUT TO THE SCREEN. THE SECOND INDEX INDICATES
      C                        WHICH SHOT: 1 FOR DATA, 2 FOR REFERENCE
      C         ICOM(51)       THIS ARRAY CONTAINS ALL THE VALID COMMANDS
      C         TITLE(33)      THIS ARRAY IS USED TO STORE THE TITLE OF THE REPORT
      C         SCR(20)        THESE TWO ARRAYS ARE SCRATCH ARRAYS USED FOR VARIOUS
      C         ISCR(20)       PURPOSES BY THE PROGRAM.
      C         BDAT(9)        THIS ARRAY IS USED TO STORE THE CURRENT DATE IN NINE
      C                        ASCII CHARACTERS.  BYTE OR LOGICAL*1 DATA TYPE
      C
```

```
C       THE FLAGS ARE DEFINED AS FOLLOWS: (ALL BYTE OR LOGICAL*1 DATA TYPE)
C
C       AUTO    IF SET, PICK POINTS WILL BE SELECTED AUTOMATICALLY.  IF RESET,
C               PICK POINTS WILL BE SELECTED MANUALLY.
C       AVE     IF SET, A RUNNING AVERAGE WILL BE CALCULATED.
C       COMP    IF SET, DATA WILL BE COMPENSATED FOR RANGE SQUARED, LOG
C               AMPLIFICATION, ZERO OFFSET AS INDICATED.
C       DATA    IF SET, THE DATA SHOT WILL BE USED FOR THE DISPLAY, ID,
C               AND LIST COMMANDS.  OTHERWISE THE REFERENCE SHOT WILL BE USED.
C       DISP    IF SET, THE DATA DISPLAY IS ACTIVE.
C       FIRST   SET TO INDICATE THE FIRST TIME THROUGH THE PROGRAM.
C       LIST    IF SET, THE SUBROUTINE 'FILIST' WILL PRINT LIDAR DATA AS WELL
C               AS HEADER INFORMATION.  IF RESET, ONLY HEADER INFORMATION IS
C               PRINTED
C       NEWD    SET TO INDICATE NEW DATA IN THE DATA ARRAY.  DISPLAY WILL NEED
C               TO BE CHANGED.
C       NEWR    SET TO INDICATE NEW DATA IN THE REFERENCE ARRAY.  DISPLAY WILL
C               NEED TO BE CHANGED.
C       NEWO    A NEW OPACITY VALUE HAS BEEN CALCULATED WHICH IS NOT YET IN THE
C               REPORT ARRAYS.
C       OUT     IF SET, AN OUTPUT FILE IS OPEN.
C       PICK    SET TO INDICATE BOTH PICK POINTS WILL BE CHANGED
C       PLUME   IF SET, THE PLUME LOCATION HAS ALREADY BEEN FOUND FOR THIS SHOT
C       REF     IF SET, THE REFERENCE  WILL BE USED IN THE OPACITY CALCULATION,
C               OTHERWISE IT WILL NOT.
C       RESID   SET TO INDICATE RESIDUAL PLUME CORRECTION WILL BE MADE
C       RNRF    IF SET, RN AND RF HAVE BEEN CALCULATED.
C       SCREEN  IF SET, THE DISPLAY NEEDS TO BE RECALCULATED AND DISPLAYED
C       SPLIT   IF SET, THE DISPLAY WILL BE SPLIT WITH EACH HALF SYMMETRICAL
C               ABOUT THE APPROPRIATE PICK POINT.
C       T2      IF SET, T-SQUARED (GEOMETRIC) CORRECTION IS PERMITTED, IF RESET
C               IT IS SUPPRESSED.
C       VT100   IF SET, THE TERMINAL IS IN THE VT100 MODE (132 CHARACTERS
C               PER LINE, GRAPHIC CHARACTER SET, ETC.)
C
C               THE FOLLOWING VARIABLES ARE LOGICAL*1 OR BYTE DATA TYPE.
C
C       DCR     ONE CHARACTER SCRATCH VARIABLE
C       ESC     ONE CHARACTER CONTAINING ASCII ESCAPE CODE
C
C               THE FOLLOWING VARIABLES ARE INTEGERS.
C
C       IC      USED TO ACCEPT CHARACTER INPUT FROM THE KEYBOARD AND AS
C               THE PLOTTING CHARACTER.
C       ID      USED TO SELECT DISPLAY, 1 FOR DATA, 2 FOR REFERENCE
C       IERR    SUBROUTINE ERROR CODE.  IF NOT ZERO, AN ERROR HAS OCCURRED.
C       IF      FILE OR SHOT NUMBER FROM SOURCE FILE.
C       IFAR    FAR PICK POINT IN NANOSECONDS AS ENTERED BY OPERATOR
C       IHRES   HORIZONTAL DISPLAY RESOLUTION, DATA POINTS PER DISPLAY POINT
C       IL      SELECTS LINE ON THE SCREEN FOR PLOTTING
C       INC     SAMPLE INTERVAL IN NANOSECONDS
C       INDEX   POINT IN DATA ARRAY USED FOR NORMALIZATION
C       IOFF    ZERO OFFSET FOR PLOTTING ON THE SCREEN
C       IOP     OPACITY ROUNDED TO THE NEAREST INTEGER.
C       IOPSIG  SO (STD. DEV.) ROUNDED TO THE NEAREST INTEGER.
C       IP      PLOT VARIABLE, 0<=IP=<64
```

```
C       IRKD    ASSOCIATE VARIABLE FOR DIRECT ACCESS SOURCE FILE.
C       ITCNT   IN REPORT ARRAYS, THE FIRST SHOT INCLUDED IN THE LATEST
C               RUNNING AVERAGE
C       ITO     TO IN NANOSECONDS. (ZERO REFERENCE FOR RANGE-SQUARED CORRECTION
C       IVRES   VERTICAL DISPLAY RESOLUTION
C       IWSTAT  RETURNS STATUS FROM WAIT SUBROUTINE
C       I132    NUMBER OF DATA POINTS NEEDED TO MAKE 132 DISPLAY POINTS
C       J       LOW INDEX OF DATA TO BE USED FOR DISPLAY
C       JFAR    FAR PICK POINT EXPRESSED IN SAMPLE INTERVALS
C       JIN     READ SELECT VARIABLE: 1 FOR DATA, 2 FOR REFERENCE, 3 FOR SCRATCH
C       JNEAR   NEAR PICK POINT EXPRESSED IN SAMPLE INTERVALS
C       J1      HIGH INDEX OF DATA TO BE USED FOR LEFT HALF OF DISPLAY
C       K       HIGH INDEX OF DATA TO BE USED FOR DISPLAY
C       KFAR    MAX(JNEAR,JFAR) USED AS THE DE FACTO FAR PICK POINT IN SAMPLE
C               INTERVALS FOR CALCULATINF THE DISPLAY AND OPACITY. (SAFETY
C               FACTOR IN CASE OF ERROR INPUTTING PICK POINTS)
C       KFAR1   END DATA POINT OF FAR PICK INTERVAL
C       KFF     KFAR CONVERTED TO NANOSECONDS. STORED AS FAR PICK POINT IN
C               REPORT ARRAYS
C       KNEAR   MIN(JNEAR,JFAR) USED AS DE FACTO NEAR PICK POINT FOR
C               CALCULATIONS. (SAFETY FACTOR AS IN KFAR)
C       KNEAR1  END DATA POINT OF NEAR PICK INTERVAL
C       KNN     KNEAR CONVERTED TO NANOSECONDS.  STORED AS NEAR PICK POINT
C               IN REPORT ARRAYS
C       K1      LOW INDEX OF DATA USED IN RIGHT HALF OF SPLIT DISPLAY
C       LIMLO   INDEX OF NEAR LIMIT FOR AUTOMATIC PICK POINT SEARCH
C       LIMHI   INDEX OF FAR LIMIT FOR AUTOMATIC PICK POINT SEARCH
C       NAVE    NUMBER OF OPACITIES IN THE CURRENT RUNNING AVERAGE
C       NE      IN SPLIT DISPLAY, THE NUMBER OF DATA POINTS TO THE LEFT OF
C               KNEAR AND TO THE RIGHT OF KFAR1
C       NEAR    NEAR PICK POINT AS ENTERED BY THE OPERATOR
C       NM      IN SPLIT DISPLAY, THE NUMBER OF DATA POINTS TO THE RIGHT OF
C               KNEAR1 AND TO THE LEFT OF KFAR
C       NOPAC   NUMBER OF SHOTS IN THE REPORT ARRAY
C       NOPAC1  FIRST SHOT OF REPORT ARRAYS USED IN THE PRINTED REPORT
C       NOPAC2  NUMBER OF SHOTS IN THE PRINTED REPORT
C       NPLUM   PLUME LOCATION IN NANOSECONDS
C       NPL1    NEAR SIDE OF PLUME IN NANOSECONDS
C       NPL2    FAR SIDE OF PLUME IN NANOSECONDS
C       NSIG    NUMBER OF SO'S IN THE CURRENT RUNNING AVERAGE
C       NSTK    STACK LOCATION IN NANOSECONDS
C       NX      IN UNDIVIDED DISPLAY, THE NUMBER OF POINTS TO BE ADDED TO
C               THE LEFT OF KNEAR OR THE RIGHT OF KFAR1 TO FILL THE DISPLAY
C
C       ALL OTHER INTEGERS ARE COUNTERS, DUMMY VARIABLES, OR INDEXES IN
C       DO LOOPS.
C
C       THE FOLLOWING VARIABLES ARE FLOATING POINT VARIABLES (REAL*4)
C
C       A       TEMPORARY VARIABLE USED IN PRINTING REPORTS
C       AZ      AZIMUTH ANGLE IN DEGREES, USED IN PRINTING HEADER
C       AZSTK   STACK AZIMUTH ANGLE
C       A1      DN+1E-15, USED IN CALCULATING OPACITY
C       A2      DF+1E-15, USED IN CALCULATING OPACITY
C       A3      RN+1E-15, USED IN CALCULATING OPACITY
C       A4      RF+1E-15, USED IN CALCULATING OPACITY
```

```
         C       B        TEMPORARY VARIABLE USED IN PRINTING REPORTS
         C       B1       DSIGN, USED IN CALCULATING SO
         C       B2       DSIGF, USED IN CALCULATING SO
         C       B3       RSIGN, USED IN CALCULATING SO
         C       B4       RSIGF, USED IN CALCULATING SO
         C       C        TEMPORARY VARIABLE USED IN PRINTING REPORTS
         C       CH       TEMPORARY VARIABLE USED FOR SCREEN OUTPUT
         C       D        TEMPORARY VARIABLE USED IN PRINTING REPORTS
         C       DF       AVERAGE VALUE OF DATA IN FAR PICK INTERVAL
         C       DN       AVERAGE VALUE OF DATA IN NEAR PICK INTERVAL
         C       DSIGF    STANDARD DEVIATION OF DF
         C       DSIGN    STANDARD DEVIATION OF DN
         C       EL       ELEVATION ANGLE IN DEGREES, USED IN PRINTING HEADER
         C       ELSTK    STACK TOP ELEVATION ANGLE
         C       OP       OPACITY
         C       OPSIG    SO (STANDARD DEVIATION OF OPACITY
         C       OPSUM    ACCUMULATED OPACITIES FOR RUNNING AVERAGE
         C       OSIGSM   ACCUMULATED SO'S FOR RUNNING AVERAGE
         C       R        VARIABLE USED TO CALCULATE DISPLAY ARRAYS
         C       RF       AVERAGE VALUE OF REFERENCE IN FAR PICK INTERVAL
         C       RN       AVERAGE VALUE OF REFERENCE IN NEAR PICK INTERVAL
         C       RSIGF    STANDARD DEVIATION OF RF
         C       RSIGN    STANDARD DEVIATION OF RN
         C       RSUM     VARIABLE USED TO CALCULATE DISPLAY ARRAYS
         C       SAVE     LENGTH OF RUNNING AVERAGE IN MINUTES (SPECIFIED BY OPERATOR)
         C       SAVEC    MINUTES IN CURRENT RUNNING AVERAGE
         C       SIGSUM   ACCUMULATED SO'S FOR WHOLE REPORT
         C       STIM     STARTING TIME OF CURRENT RUNNING AVERAGE IN MINUTES
         C       SUM      ACCUMULATED OPACITIES FOR WHOLE REPORT
         C       TIME     TIME OF CURRENT SHOT
         C       VAVE     OPACITY STANDARD FOR AVERAGE
         C       VSIN     OPACITY STANDARD FOR SINGLE EVENT
         C
         C       THERE ARE ALSO TWO DOUBLE PRECISION FLOATING POINT VARIABLES: DOUBLE,
         C       AND DOUBL1 WHICH ARE USED IN DISPLAYING THE CALCULATED OPACITY
         C
                 BYTE DISP,VT100,DATA,NEWD,NEWR,COMP,T2,REF,SCREEN,OUT,NEWO
                 BYTE AUTO,AVE,FIRST,RNRF,ESC,LIST,SPLIT,RESID,PLUME
                 COMMON VT100
                 COMMON /ACC1/ITCNT,STIM,SAVEC,NSIG,NAVE,OSIGSM,OPSUM
                 COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
                 COMMON /FNUM/IF
                 COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,OP,
                 1OPSIG,OPC
                 COMMON /RFLAG/RNRF
                 COMMON /RESO/IHRES,IVRES
                 COMMON /AVGE/SAVE,AVE
                 COMMON /RECORD/IRKD
                 COMMON /NFLAGS/COMP,T2,ITO
                 COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
                 COMMON /AUXIL/IAUX(52,3)
                 COMMON /LDATA/IDAT(2048,2)
                 COMMON /PICK2/INC,KNEAR,KFAR
                 COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
                 COMMON /REPORT/REP(14,136),IREP(12,136)
                 COMMON /IDSPL/IDISP(132,2),J,K,K1,KNEAR1,KFAR1,DISP,SPLIT
```

```
0021                COMMON /OUTFIL/IOFILE(9)
0022                COMMON /LIMITS/LIMLO,LIMHI
0023                COMMON /STACK/NPLUM,NSTK,ELSTK,AZSTK
0024                COMMON /COMMAN/ICOM(51)
0025                DATA ICOM/1HS,2HSO,2HST,1HR,2HRE,1HD,2HDA,2HRD,2HRR,1HN,2HNE,1HF
                    1,2HFA,2HFI,2HID,1HL,2HLI,2HNO,1HY,2HYE,2HT2,1HC,2HCO,2HTO
                    2,2HDI,2HDX,2HPK,1HH,2HHE,2HRC,1HO,2HOP,2HOU,1HB,2HBE,1HE,2HEN
                    3,2HAV,1HA,2HAC,1HP,2HPR,2HOF,2HEX,2HAU,2HSL,2HRS,2HDY,2HBA,2HFT
                    4,2HWD/
0026                DATA ESC/"33/
0027                VT100=.FALSE.     !TERMINAL IS IN VT52 MODE
0028                FIRST=.TRUE.      !THIS IS THE FIRST TIME THROUGH THE PROGRAM
            C
            C       ENTRY POINT FOR START ROUTINE
            C       INITIALIZE VARIABLES AND FLAGS
            C
0029        10      DO 20 I=1,156     !:ST
0030                IAUX(I,1)=0
0031        20      CONTINUE
0032                DO 30 I=1,4096
0033                IDAT(I,1)=0
0034        30      CONTINUE
0035                NOPAC=0           !NUMBER OF SHOTS IN REPORT ARRAY
0036                NOPAC1=1          !FIRST SHOT FOR PRINTED REPORT
0037                NOPAC2=0          !NUMBER OF SHOTS IN PRINTED REPORT
0038                SAVE=0.0          !MINUTES IN RUNNING AVERAGE
0039                NAVE=0            !NUMBER OF OPACITIES IN CURRENT RUNNING AVERAGE
0040                IHRES=16          !HORIZONTAL DISPLAY RESOLUTION
0041                IVRES=4           !VERTICAL DISPLAY RESOLUTION
0042                AUTO=.FALSE.      !PICK POINTS WILL BE SELECTED MANUALLY
0043                RESID=.FALSE.     !NO RESIDUAL PLUME CORRECTION WILL BE MADE
0044                PLUME=.FALSE.     !PLUME HAS NOT BEEN FOUND
0045                PICK=.FALSE.      !PK COMMAND IS NOT ACTIVE
0046                DISP=.FALSE.      !DISPLAY IS OFF
0047                DATA=.TRUE.       !DATA, NOT REFERENCE WILL BE DISPLAYED
0048                NEWD=.TRUE.       !NEW DATA ARRAY
0049                NEWR=.TRUE.       !NEW REF ARRAY
0050                COMP=.TRUE.       !DATA WILL BE COMPENSATED
0051                T2=.TRUE.         !T2 CORRECTION IS ALLOWED
0052                REF=.TRUE.        !REFERENCE WILL BE USED IN OPACITY CALCULATION
0053                SCREEN=.TRUE.     !SCREEN NEEDS TO BE REFRESHED.
0054                OUT=.FALSE.       !OUTPUT FILE IS NOT OPEN
0055                NEWO=.FALSE.      !THERE IS NO NEW OPACITY AVAILABLE
0056                AVE=.FALSE.       !A RUNNING AVERAGE WILL NOT BE CALCULATED
0057                RNRF=.FALSE.      !RN AND RF HAVE NOT BEEN CALCULATED
0058                SPLIT=.FALSE.     !DISPLAY IS NOT SPLIT
0059                ID=1              !DATA ARRAY IS SELECTED FOR DISPLAY
0060                IF=1              !FIRST SHOT WILL BE READ FROM THE SOURCE FILE
0061                ITO=710           !TO IN NANOSECONDS
0062                LIMLO=1
0063                LIMHI=2048
0064                NPLUM=10000       !INITIAL VALUE FOR PLUME SEARCH
            C
            C       MAKE SURE TERMINAL IS IN VT52 MODE
            C
0065                IF(.NOT.VT100)GOTO 60
```

```
                 WRITE (5,2000)ESC,"143
                 VT100=.FALSE.
       60        IF(.NOT.FIRST)GOTO 130
                 CALL WAIT(10,2,IWSTAT)
       C
       C         SHOULD ANALYSIS START FROM AN OLD FILE?
       C
                 WRITE(5,2020)
                 READ(5,2080)IC
                 IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 70
                 CALL OLDFIL
       70        CALL SOURCE      !:S :SO
                 IF(.NOT.FIRST)GOTO 130
                 CALL NEARP
                 CALL FAR
                 CALL FILE
                 CALL AVERAQ
       C
       C         DISPLAY PROMPT (:), WAIT FOR COMMAND AND GO TO SELECTED
       C         ROUTINE
       C
       130       IF(VT100)WRITE(5,2060)ESC
                 FIRST=.FALSE.
                 WRITE(5,2070)
                 READ(5,2080)IC
                 DO 140 I=1,51
                 IF(IC.EQ.ICOM(I))GOTO 150
       140       CONTINUE
       150       GOTO(70,70,10,190,170,180,180,190,200,210,210,220,220,230,240
                 1,270,270,280,290,290,300,310,310,320,540,840,205,600,600,865
                 2,890,890,960,990,990,1010,1010,1060,1070,1070,1130,1130,400
                 3,1260,420,440,460,480,500,160,520)I
       C
       C         INVALID COMMAND
       C
       160       IF(VT100) CALL ERLINE
                 WRITE(5,2100)IC
                 GOTO 130          !GET NEW COMMAND
       190       CALL RD           !:R :RD
                 IF(DATA.OR.AUTO)GOTO 195
                 GOTO 130
       195       PLUME=.FALSE.
                 IF(.NOT.AUTO)GOTO 197
       190       CALL SEARCH(NPLUM,NPL1,NPL2)
                 NPLUM=(NPL1+NPL2)/2
                 PLUME=.TRUE.
       196       NEAR=NPL1
                 IFAR=NPL2
                 CALL NEARP
                 CALL FAR
       197       IF(DISP)CALL DISPLA
                 IF(DISP)CALL OPAC
                 GOTO 130
       170       CALL REFER        !:RE
                 GOTO 197
       180       CALL DTA          !:D :DA
```

```
            GOTO 197
      200   CALL RR         !:RR
            IF(IAUX(7,1).GT.0)GOTO 204
            IF(.NOT.DATA.AND.DISP)CALL DISPLA
            GOTO 130
      204   IF(AUTO)GOTO 196
            IF(.NOT.DATA.AND.DISP)CALL DISPLA
            IF(DISP)CALL OPAC
            GOTO 130
      210   CALL NEARP      !:N :NE
            GOTO 197
      220   CALL FAR        !:F :FA
            GOTO 197
      230   CALL FILE       !:FI
            GOTO 130
      240   CALL IDENT      !:ID
            GOTO 130
      270   CALL LISTF      !:L :LI
            GOTO 130
      280   CALL NO         !:NO
            IF(.NOT.REF)GOTO 130
            REF=.FALSE.
            RNRF=.FALSE.
            IF(AUTO)GOTO 196
            GOTO 195
      290   CALL YES        !:Y :YE
            IF(REF)GOTO 130
            RNRF=.FALSE.
            REF=.TRUE.
            IF(AUTO)GOTO 196
            GOTO 195
      300   CALL TEE2       !:T2
            GOTO 195
      310   CALL COMPEN     !:C :CO
            GOTO 195
      320   CALL TO         !:TO
            READ(5,2080)IC
            GOTO 195
      600   CALL HELP       !:H :HE
            GOTO 130
      540   IF(.NOT.VT100)CALL TERM !:DI
            CALL DSP
            IF(AUTO)GOTO 198
            CALL OPAC
            GOTO 130
      840   CALL DL         !:DX
            GOTO 197
      205   CALL NEARP      !:PK
            CALL FAR
            GOTO 197
      865   CALL RC         !:RC
            GOTO 130
      890   CALL OPAC       !:O :OP
            GOTO 130
      960   CALL OUTP       !:OU
            GOTO 130
```

```
FORTRAN IV-PLUS V02-51E          10:37:50    04-MAY-81         PAGE 10
OMEG5A.FTN        /TR:BLOCKS/WR

0165     990      CALL BEGIN        !:B :BE
0166              GOTO 130
0167     1010     CALL EN           !:E :EN
0168              GOTO 130
0169     1060     CALL AVERAG       !:AV
0170              GOTO 130
0171     1070     CALL ACC          !:A :AC
0172              GOTO 130
0173     1130     CALL PRINT        !:P :PR
0174              GOTO 130
0175     400      CALL OLDFIL       !:OF
0176              GOTO 130
0177     420      CALL AUT          !:AU
0178              IF(AUTO)CALL SET
0179              GOTO 130
0180     440      CALL SET          !:SL
0181              GOTO 130
0182     460      CALL RES          !:RS
0183              GOTO 130
0184     480      CALL DY           !:DY
0185              GOTO 197
0186     500      [illegible]GOTO 196        !:BA
0187              [illegible]
         C510     CALL FT
         C        GOTO 130
0188     520      CALL TERM         !:WD
0189              CALL ERLINE
0190              GOTO 130
0191     1260     CALL EX           !:EX
0192              GOTO 130
0193     2000     FORMAT('+',2A1)
0194     2020     FORMAT('$DO YOU WANT TO START FROM AN OLD FILE? ')
0195     2060     FORMAT(1H+,A1,'[13;1H')
0196     2070     FORMAT('$:')
0197     2080     FORMAT(A2)
0198     2100     FORMAT(17X,A2,' IS NOT A VALID COMMAND.  TRY AGAIN '
                  1,'OR TYPE HELP.')
0199              END
```

```
FORTRAN IV-PLUS V02-51E          10:37:50    04-MAY-81          PAGE 11
OMEG5A.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                    ATTRIBUTES

   1     $CODE1   003044   786              RW,I,CON,LCL
   2     $PDATA   000162    57              RW,D,CON,LCL
   3     $IDATA   000226    75              RW,D,CON,LCL
   4     $VARS    000022     9              RW,D,CON,LCL
   6     .$$$$.   000002     1              RW,D,OVR,GBL
   7     ACC1     000026    11              RW,D,OVR,GBL
   8     TFLAGS   000006     3              RW,D,OVR,GBL
   9     FNUM     000002     1              RW,D,OVR,GBL
  10     ACC2     000056    23              RW,D,OVR,GBL
  11     RFLAG    000002     1              RW,D,OVR,GBL
  12     RESO     000004     2              RW,D,OVR,GBL
  13     AVGE     000006     3              RW,D,OVR,GBL
  14     RECORD   000002     1              RW,D,OVR,GBL
  15     NFLAGS   000004     2              RW,D,OVR,GBL
  16     NPC      000010     4              RW,D,OVR,GBL
  17     AUXIL    000470   156              RW,D,OVR,GBL
  18     LDATA    020000  4096              RW,D,OVR,GBL
  19     PICK2    000006     3              RW,D,OVR,GBL
  20     PICKS    000010     4              RW,D,OVR,GBL
  21     REPORT   025200  5440              RW,D,OVR,GBL
  22     IDSPL    001034   270              RW,D,OVR,GBL
  23     OUTFIL   000022     9              RW,D,OVR,GBL
  24     LIMITS   000004     2              RW,D,OVR,GBL
  25     STACK    000014     6              RW,D,OVR,GBL
  26     COMMAN   000146    51              RW,D,OVR,GBL


VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AUTO   L*1  20-000004   AVE    L*1  13-000004   AZSTK  R*4  25-000010   COMP   L*1  15-000000   DATA   L*1   8-000002
 DF     R*4  10-000032   DISP   L*1  22-001032   DN     R*4  10-000022   DSIGF  R*4  10-000036   DSIGN  R*4  10-000026
 ELSTK  R*4  25-000004   ESC    L*1   4-000001   FIRST  L*1   4-000000   I      I*2   4-000004   IC     I*2   4-000014
 ID     I*2   8-000000   IF     I*2   9-000000   IFAR   I*2  20-000002   IHRES  I*2  12-000000   INC    I*2  19-000000
 IRKD   I*2  14-000000   ITCNT  I*2   7-000000   ITO    I*2  15-000002   IVRES  I*2  12-000002   IWSTAT I*2   4-000012
 J      I*2  22-001020   K      I*2  22-001022   KFAR   I*2  19-000004   KFAR1  I*2  22-001030   KNEAR  I*2  19-000002
 KNEAR1 I*2  22-001026   K1     I*2  22-001024   LIMHI  I*2  24-000002   LIMLO  I*2  24-000000   LIST   L*1   4-000002
 NAVE   I*2   7-000014   NEAR   I*2  20-000000   NEWD   L*1   8-000004   NEWO   L*1  10-000001   NEWR   L*1   8-000005
 NOPAC  I*2  16-000000   NOPAC1 I*2  16-000002   NOPAC2 I*2  16-000004   NPLUM  I*2  25-000000   NPL1   I*2   4-000016
 NPL2   I*2   4-000020   NSIG   I*2   7-000012   NSTK   I*2  25-000002   OP     R*4  10-000042   OPC    R*4  10-000052
 OPSIG  R*4  10-000046   OPSUM  R*4   7-000022   OSIGSM R*4   7-000016   OUT    L*1  16-000006   PICK   R*4   4-000006
 PLUME  L*1  20-000006   REF    L*1  10-000000   RESID  L*1  20-000005   RF     R*4  10-000012   RN     R*4  10-000002
 RNRF   L*1  11-000000   RSIGF  R*4  10-000016   RSIGN  R*4  10-000006   SAVE   R*4  13-000000   SAVEC  R*4   7-000006
 SCREEN L*1   8-000003   SPLIT  L*1  22-001033   STIM   R*4   7-000002   T2     L*1  15-000001   VT100  L*1   6-000000


ARRAYS

 NAME   TYPE  ADDRESS        SIZE          DIMENSIONS

 IAUX   I*2  17-000000  000470    156      (52,3)
```

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FORTRAN IV-PLUS V02-51E          10:37:50    04-MAY-81          PAGE 12
OMEGSA.FTN        /TR:BLOCKS/WR

 ICOM    I*2  26-000000  000146    51     (51)
 IDAT    I*2  18-000000  020000  4096     (2048,2)
 IDISP   I*2  22-000000  001020   264     (132,2)
 IOFILE  I*2  23-000000  000022     9     (9)
 IREP    I*2  21-016700  006300  1632     (12,136)
 REP     R*4  21-000000  016700  3808     (14,136)

LABELS

 LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS

 10       1-000040       20          **          30          **          60       1-000442       70       1-000566
 130      1-000652       140         **          150      1-001040       160      1-001062       170      1-001374
 180      1-001414       190      1-001140       195      1-001176       196      1-001264       197      1-001326
 198      1-001216       200      1-001434       204      1-001510       205      1-002322       210      1-001572
 220      1-001612       230      1-001632       240      1-001654       270      1-001676       280      1-001720
 290      1-001776       300      1-002056       310      1-002100       320      1-002122       400      1-002574
 420      1-002616       440      1-002656       460      1-002700       480      1-002722       500      1-002744
 520      1-002770       540      1-002216       600      1-002174       840      1-002300       865      1-002354
 890      1-002376       960      1-002420       990      1-002442       1010     1-002464       1060     1-002506
 1070     1-002530       1130     1-002552       1260     1-003022       2000'    3-000000       2020'    3-000006
 2060'    3-000062       2070'    3-000100       2080'    3-000106       2100'    3-000112

FUNCTIONS AND SUBROUTINES REFERENCED

 ACC     AUT     AVERAG  BEGIN   COMPEN  DISPLA  DL      DSP     DTA     DY      EN      ERLINE  EX      FAR     FILE    HELP
 IDENT   LISTF   NEARP   NO      OLDFIL  OPAC    OUTP    PRINT   RC      RD      REFER   RES     RR      SEARCH  SET     SOURCE
 TEE2    TERM    TO      WAIT    YES

TOTAL SPACE ALLOCATED = 053020 11016
```

```
0001                SUBROUTINE ERLINE
           C
           C        THIS SUBROUTINE ERASES THE BOTTOM LINE ON THE DISPLAY
           C
0002                WRITE(5,1000)"33,"33,"33
0003                RETURN
0004       1000     FORMAT(1H+,A1,'[14;1H',A1,'[2K',A1,'[13;1H')
0005                END
```

```
FORTRAN IV-PLUS V02-51E          10:39:10    04-MAY-81          PAGE 14
OMEG5A.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

  1     $CODE1   000074     30             RW,I,CON,LCL
  2     $PDATA   000002      1             RW,D,CON,LCL
  3     $IDATA   000036     15             RW,D,CON,LCL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 ERLINE       1-000000

LABELS

 LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS

 1000'   3-000000

TOTAL SPACE ALLOCATED = 000134    46

NO FPP INSTRUCTIONS GENERATED
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FORTRAN IV-PLUS V02-51E        10:39:14    04-MAY-81          PAGE 15
OMEG5A.FTN          /TR:BLOCKS/WR

                    SUBROUTINE SEARCH(NSTART,NP,NP1)
        C
        C           THIS SUBROUTINE SEARCHES FOR A STACK OR PLUME STARTING AT NSTART.
        C           THE FRONT EDGE OF THE PLUME IS RETURNED IN NP; THE BACK EDGE IN NP1.
        C
        C           NP IS SET TO 0 IF NO PLUME IS FOUND.
        C
                    COMMON /AUXIL/IAUX(52,3)
                    COMMON /LDATA/IDAT(2048,2)
                    COMMON /LIMITS/LIMLO, LIMHI
                    INC=IAUX(11,1)            !SAMPLE INTERVAL IN NANOSECONDS
                    NST=NSTART/INC+1          !STARTING POINT INDEX
                    NST1=NST-1
                    NST2=NST
                    IF(NST.GT.LIMHI.OR.NST.LT.LIMLO)GOTO 110        !OUTSIDE LIMITS
          10        IF(NST2.LE.LIMHI)GOTO 20                 !LOOK AT NEXT HIGHER POINT
                    IF(NST1.LT.LIMLO)GOTO 110                !OUTSIDE LIMITS
                    GOTO 30                                  !LOOK AT NEXT LOWER POINT
          20        IF(IDAT(NST2,1).EQ.255)GOTO 40           !FOUND PEAK
                    NST2=NST2+1
                    IF(NST1.GE.LIMLO)GOTO 30                 !LOOK AT NEXT LOWER POINT
                    IF(NST2.GT.LIMHI)GOTO 110                !OUTSIDE LIMITS
                    GOTO 20                                  !LOOK AT NEXT HIGHER POINT
          30        IF(IDAT(NST1,1).EQ.255)GOTO 50           !FOUND PEAK
                    NST1=NST1-1
                    GOTO 10                                  !REPEAT SEARCH CYCLE
          40        I=NST2
                    GOTO 60
          50        I=NST1
          60        J=I-1
          70        IF(J.LT.LIMLO)GOTO 90
                    IF(IDAT(J,1).LT.255)GOTO 90
                    J=J-1
                    GOTO 70
          90        NP=J*INC                       !NEAR EDGE OF PLUME
         100        I=I+1
                    IF(I.GE.LIMHI)GOTO 105
                    IF(IDAT(I,1).GE.IDAT(I-1,1))GOTO 100
         105        NP1=(I-1)*INC                  !FAR EDGE OF PLUME
                    RETURN
         110        NP=0                           !PLUME NOT LOCATED
                    RETURN
                    END
```

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FORTRAN IV-PLUS V02-51E        10:39:14    04-MAY-81          PAGE 16
OMEG5A.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                ATTRIBUTES

  1     $CODE1   000502   161           RW,I,CON,LCL
  4     $VARS    000014     6           RW,D,CON,LCL
  6     AUXIL    000470   156           RW,D,OVR,GBL
  7     LDATA    020000  4096           RW,D,OVR,GBL
  8     LIMITS   000004     2           RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 SEARCH       1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 I      I*2   4-000010    INC    I*2   4-000000    J      I*2   4-000012    LIMHI  I*2   8-000002    LIMLO  I*2   8-000000
 NP     I*2   F-000004*   NP1    I*2   F-000006*   NST    I*2   4-000002    NSTART I*2   F-000002*   NST1   I*2   4-000004
 NST2   I*2   4-000006

ARRAYS

 NAME   TYPE  ADDRESS        SIZE         DIMENSIONS

 IAUX   I*2   6-000000  000470   156      (52,3)
 IDAT   I*2   7-000000  020000  4096      (2048,2)

LABELS

 LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 10      1-000106         20      1-000136         30      1-000210         40      1-000242         50      1-000260
 60      1-000274         70      1-000314         90      1-000356         100     1-000400         105     1-000440
 110     1-000466

TOTAL SPACE ALLOCATED = 021212   4421

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        10:39:29    04-MAY-81           PAGE 17
OMEG5A.FTN        /TR:BLOCKS/WR

0001                  SUBROUTINE RDCHK(LL)
             C
             C        THIS SUBROUTINE ACCEPTS AN INPUT FROM THE TERMINAL, CHECKS TO VERIFY
             C        THAT IT IS AN INTEGER IN THE RANGE FROM 0 TO 32,767, AND RETURNS THE
             C        VALUE AS LL.  IF A NON NUMERIC CHARACTER IS RECEIVED, NEW INPUT IS
             C        REQUESTED.  IF THE NUMBER IS OUTSIDE THE INDICATED BOUNDS, IT IS
             C        FORCED TO 0 OR 32767, WHICHEVER IS CLOSEST.
             C
0002                  BYTE VT100
0003                  COMMON VT100
0004         10       READ(5,*,ERR=20)AA
0005                  GOTO 30
0006         20       IF(VT100)CALL ERLINE
0007                  WRITE(5,100)
0008                  GOTO 10
0009                  ENTRY CHECK(BB,LL)
             C
             C        THIS ROUTINE FORCES THE VALUE OF THE NUMBER BB TO BE IN THE RANGE
             C        FROM 0 TO 32767 AND ASSIGNS THE INTEGER PART OF THE NUMBER TO LL
             C
0010                  AA=BB
0011         30       IF(AA.GT.32767.0)AA=32767.0
0012                  IF(AA.LT.0.0)AA=0.0
0013                  LL=AA
0014                  RETURN
0015         100      FORMAT(1H$,16X,'INPUT ERROR,  TRY AGAIN ')
0016                  END
```

```
FORTRAN IV-PLUS V02-51E          10:39:29     04-MAY-81           PAGE 18
OMEG5A.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME         SIZE                 ATTRIBUTES

  1     $CODE1  000246    83               RW,I,CON,LCL
  2     $PDATA  000004     2               RW,D,CON,LCL
  3     $IDATA  000042    17               RW,D,CON,LCL
  4     $VARS   000004     2               RW,D,CON,LCL
  6     .$$$$.  000002     1               RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 CHECK         1-000136    RDCHK         1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AA      R*4   4-000000    BB      R*4   F-000002*   LL      I*2   3-000036*   VT100   L*1   6-000000

LABELS

 LABEL     ADDRESS         LABEL     ADDRESS         LABEL     ADDRESS         LABEL     ADDRESS         LABEL     ADDRESS

 10        1-000022        20        1-000064        30        1-000172        100'      3-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000322    105

SYO:[101,1]OMEG5A,SYO:[101,1]OMEG5A/-SP=SYO:[101,1]OMEG5A
```

```
FORTRAN IV-PLUS V02-51E        09:18:51     27-FEB-81            PAGE 1
OMEG5B.FTN         /TR:BLOCKS/WR

                SUBROUTINE NEARP
          C
          C     SET NEAR PICK POINT
          C
                BYTE VT100, DATA, SCREEN, NEWD, NEWR, RNRF, AUTO, RESID, PLUME
                BYTE REF, NEWO
                COMMON VT100
                COMMON /AUXIL/IAUX(52,3)
                COMMON /CALNOR/W, Z, INC
                COMMON /LIMITS/LIMLO, LIMHI
                COMMON /TFLAGS/ID, DATA, SCREEN, NEWD, NEWR
                COMMON /PICKS/NEAR, IFAR, AUTO, RESID, PLUME
                COMMON /RFLAG/RNRF
                COMMON /ACC2/REF, NEWO, RN, RSIGN, RF, RSIGF, DN, DSIGN, DF, DSIGF, OP,
                1OPSIG, OPC
                IF(AUTO)GOTO 10
                IF(VT100)CALL ERLINE
                WRITE(5,2110)NEAR
                CALL RDCHK(NEAR)
          5     NEWD=.TRUE.
                NEWR=.TRUE.
                SCREEN=.TRUE.
                RNRF=.FALSE.
                RETURN
          10    INC=IAUX(11,1)                    !SAMPLE INTERVAL IN NANOSECONDS
                JN=NEAR/INC+1                     !INDEX OF NEAR PICK STARTING POINT
                IF(JN-1.LT.LIMLO)GOTO 70          !JN IS AT LOW END OF SEARCH RANGE
                RN=1.0
                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 20    !NO REFERENCE
                CALL NORM(JN,2)
                W=1.0
                CALL PONDER(JN,2,RN,RSIGN)
                IF(RN.LT.1.E-6)RN=1.E-6
          20    CALL NORM(JN,1)
                W=1.0
                CALL PONDER(JN,1,DN,DSIGN)
          30    OLD=DN/RN
                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 40
                CALL NORM(JN-1,2)
                W=1.0
                CALL PONDER(JN-1,2,RN,RSIGN)
                IF(RN.LT.1.E-6)RN=1.E-6
          40    CALL NORM(JN-1,1)
                W=1.0
                CALL PONDER(JN-1,1,DN,DSIGN)
                IF(DN/RN.LT.OLD)GOTO 50
                JN=JN-1
                IF(JN-1.LT.LIMLO)GOTO 70
                GOTO 30
          50    OLD=DN/RN
                JN=JN-1
                IF(JN-1.LT.LIMLO)GOTO 70
                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 60
                CALL NORM(JN-1,2)
                W=1.0
                CALL PONDER(JN-1,2,RN,RSIGN)
```

```
FORTRAN IV-PLUS V02-51E        09:18:51     27-FEB-81           PAGE 2
OMEG5B.FTN          /TR:BLOCKS/WR

0053                IF(RN.LT.1.E-6)RN=1.E-6
0054      60        CALL NORM(JN-1,1)
0055                W=1.0
0056                CALL PONDER(JN-1,1,DN,DSIGN)
0057                IF(DN/RN.LT.OLD)GOTO 50
0058      70        NEAR=(JN-1)*INC
0059                GOTO 5
0060      2110      FORMAT(1H$,16X,'NEAR PICK POINT IS',I6,' NS.  CHANGE TO: ')
0061                END
```

```
FORTRAN IV-PLUS V02-51E         09:18:51    27-FEB-81           PAGE 3
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

   1     $CODE1  001240   336             RW,I,CON,LCL
   2     $PDATA  000014     6             RW,D,CON,LCL
   3     $IDATA  000164    58             RW,D,CON,LCL
   4     $VARS   000006     3             RW,D,CON,LCL
   5     $TEMPS  000002     1             RW,D,CON,LCL
   6     .$$$$.  000002     1             RW,D,OVR,GBL
   7     AUXIL   000470   156             RW,D,OVR,GBL
   8     CALNOR  000012     5             RW,D,OVR,GBL
   9     LIMITS  000004     2             RW,D,OVR,GBL
  10     TFLAGS  000006     3             RW,D,OVR,GBL
  11     PICKS   000010     4             RW,D,OVR,GBL
  12     RFLAG   000002     1             RW,D,OVR,GBL
  13     ACC2    000056    23             RW,D,OVR,GBL


ENTRY POINTS

 NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS

 NEARP         1-000000


VARIABLES

 NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS

 AUTO    L*1  11-000004     DATA    L*1  10-000002     DF      R*4  13-000032     DN      R*4  13-000022     DSIGF   R*4  13-000036
 DSIGN   R*4  13-000026     ID      I*2  10-000000     IFAR    I*2  11-000002     INC     I*2   8-000010     JN      I*2   4-000000
 LIMHI   I*2   9-000002     LIMLO   I*2   9-000000     NEAR    I*2  11-000000     NEWD    L*1  10-000004     NEWO    L*1  13-000001
 NEWR    L*1  10-000005     OLD     R*4   4-000002     OP      R*4  13-000042     OPC     R*4  13-000052     OPSIG   R*4  13-000046
 PLUME   L*1  11-000006     REF     L*1  13-000000     RESID   L*1  11-000005     RF      R*4  13-000012   . RN      R*4  13-000002
 RNRF    L*1  12-000000     RSIGF   R*4  13-000016     RSIGN   R*4  13-000006     SCREEN  L*1  10-000003     VT100   L*1   6-000000
 W       R*4   8-000000     Z       R*4   8-000004


ARRAYS

 NAME    TYPE  ADDRESS         SIZE          DIMENSIONS

 IAUX    I*2   7-000000  000470     156     (52,3)


LABELS

 LABEL    ADDRESS           LABEL    ADDRESS           LABEL    ADDRESS           LABEL    ADDRESS           LABEL    ADDRESS

 5        1-000106          10       1-000144          20       1-000326          30       1-000366          40       1-000544
 50       1-000702          60       1-001072          70       1-001210          2110'    3-000000


FUNCTIONS AND SUBROUTINES REFERENCED
```

```
FORTRAN IV-PLUS V02-51E        09:18:51    27-FEB-81          PAGE 4
OMEG5B.FTN      /TR:BLOCKS/WR

 ERLINE  NORM    PONDER  RDCHK

TOTAL SPACE ALLOCATED = 002256   599
```

```
0001                SUBROUTINE FAR
          C
          C         SET FAR PICK POINT
          C
0002                BYTE VT100,DATA,SCREEN,NEWD,NEWR,RNRF,AUTO,RESID,PLUME
0003                BYTE NEWO,REF
0004                COMMON VT100
0005                COMMON /LIMITS/LIMLO,LIMHI
0006                COMMON /AUXIL/IAUX(52,3)
0007                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0008                COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
0009                COMMON /RFLAG/RNRF
0010                COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,OP,
                    1OPSIG,OPC
0011                IF(AUTO)GOTO 10
0012                IF(VT100)CALL ERLINE
0013                WRITE(5,2120)IFAR
0014                CALL RDCHK(IFAR)
0015          5     NEWD=.TRUE.
0016                NEWR=.TRUE.
0017                SCREEN=.TRUE.
0018                RNRF=.FALSE.
0019                RETURN
0020          10    INC=IAUX(11,1)                    !SAMPLE INTERVAL IN NANOSECONDS
0021                JF=IFAR/INC+1
0022                IF(JF+1.GT.LIMHI)GOTO 70          !FAR PICK IS OUTSIDE SEARCH WINDOW
0023                JN=NEAR/INC+1
0024                RF=1.0
0025                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 20   !NO REFERENCE
0026                CALL NORM(JN,2)
0027                CALL PONDER(JF,2,RF,RSIGF)
0028                IF(RF.LT.1.E-6)RF=1.E-6
0029          20    CALL NORM(JN,1)
0030                CALL PONDER(JF,1,DF,DSIGF)
0031          30    OLD=DF/RF
0032                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 40
0033                CALL NORM(JN,2)
0034                CALL PONDER(JF+1,2,RF,RSIGF)
0035                IF(RF.LT.1.E-6)RF=1.E-6
0036          40    CALL NORM(JN,1)
0037                CALL PONDER(JF+1,1,DF,DSIGF)
0038                IF(DF/RF.LT.OLD)GOTO 50
0039                JF=JF+1
0040                IF(JF+1.GT.LIMHI)GOTO 70
0041                GOTO 30
0042          50    OLD=DF/RF
0043                JF=JF+1
0044                IF(JF+1.GT.LIMHI)GOTO 70
0045                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)GOTO 60
0046                CALL NORM(JN,2)
0047                CALL PONDER(JF+1,2,RF,RSIGF)
0048                IF(RF.LT.1.E-6)RF=1.E-6
0049          60    CALL NORM(JN,1)
0050                CALL PONDER(JF+1,1,DF,DSIGF)
0051                IF(DF/RF.LT.OLD)GOTO 50
0052          70    IFAR=(JF-1)*INC
```

```
FORTRAN IV-PLUS V02-51E        09:18:56    27-FEB-81          PAGE 6
OMEG5B.FTN       /TR:BLOCKS/WR

                 GOTO 5
          2120   FORMAT(1H$,16X,'FAR PICK POINT IS',I6,' NS.  CHANGE TO: ')
                 END
```

```
FORTRAN IV-PLUS V02-51E          09:18:56     27-FEB-81           PAGE 7
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME        SIZE                 ATTRIBUTES

  1      $CODE1  001106   291              RW,I,CON,LCL
  2      $PDATA  000014     6              RW,D,CON,LCL
  3      $IDATA  000150    52              RW,D,CON,LCL
  4      $VARS   000012     5              RW,D,CON,LCL
  5      $TEMPS  000002     1              RW,D,CON,LCL
  6      .$$$$.  000002     1              RW,D,OVR,GBL
  7      LIMITS  000004     2              RW,D,OVR,GBL
  8      AUXIL   000470   156              RW,D,OVR,GBL
  9      TFLAGS  000006     3              RW,D,OVR,GBL
 10      PICKS   000010     4              RW,D,OVR,GBL
 11      RFLAG   000002     1              RW,D,OVR,GBL
 12      ACC2    000056    23              RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 FAR           1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AUTO    L*1  10-000004    DATA    L*1   9-000002    DF      R*4  12-000032    DN      R*4  12-000022    DSIGF   R*4  12-000036
 DSIGN   R*4  12-000026    ID      I*2   9-000C00    IFAR    I*2  10-000002    INC     I*2   4-000000    JF      I*2   4-000002
 JN      I*2   4-000004    LIMHI   I*2   7-000002    LIMLO   I*2   7-000000    NEAR    I*2  10-000000    NEWD    L*1   9-000004
 NEWO    L*1  12-000001    NEWR    L*1   9-000005    OLD     R*4   4-000006    OP      R*4  12-000042    OPC     R*4  12-000052
 OPSIG   R*4  12-000046    PLUME   L*1  10-000006    REF     L*1  12-000000    RESID   L*1  10-000005    RF      R*4  12-000012
 RN      R*4  12-000002    RNRF    L*1  11-000000    RSIGF   R*4  12-000016    RSIGN   R*4  12-000006    SCREEN  L*1   9-000003
 VT100   L*1   6-000000

ARRAYS

 NAME    TYPE  ADDRESS        SIZE          DIMENSIONS

 IAUX    I*2   8-000000  000470    156      (52,3)

LABELS

 LABEL    ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS

 5        1-000104         10       1-000142         20       1-000332         30       1-000360         40       1-000510
 50       1-000620         60       1-000770         70       1-001056         2120'    3-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  NORM    PONDER  RDCHK
```

```
TOTAL SPACE ALLOCATED = 002102   545
```

```
FORTRAN IV-PLUS V02-51E       09:18:59    27-FEB-81          PAGE 9
OMEG5B.FTN          /TR:BLOCKS/WR

0001                SUBROUTINE DISPLA
              C
              C     DISPLAY GENERATE AND UPDATE ROUTINE.
              C
0002                BYTE VT100,SPLIT,DATA,SCREEN,NEWD,NEWR,DISP,ESC
0003                BYTE AUTO,RESID,PLUME
0004                COMMON VT100
0005                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0006                COMMON /AUXIL/IAUX(52,3)
0007                COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
0008                COMMON /PICK2/INC,KNEAR,KFAR
0009                COMMON /RESO/IHRES,IVRES
0010                COMMON /IDSPL/IDISP(132,2),J,K,K1,KNEAR1,KFAR1,DISP,SPLIT
0011                DATA ESC/"33/
              C     IF DISPLAY IS NOT ON, GET NEW COMMAND
              C
0012                IF(.NOT.DISP)RETURN
0013                IF(SCREEN) GO TO 540
0014                IF(NEWD.AND.DATA)GO TO 540
0015                IF(NEWR.AND..NOT.DATA)GO TO 540
              C
              C     A NEW DISPLAY IS NOT NEEDED, GET NEW COMMAND
              C
0016                RETURN
              C
              C     ENTRY POINT FOR DISP COMMAND
              C
0017                ENTRY DSP
0018          540   IF(VT100)CALL ERLINE
              C
              C     THE FOLLOWING 3 STATEMENTS CHECK TO SEE IF A NEW DISPLAY MUST BE
              C     CALCULATED.  IF NOT, THE PREVIOUSLY CALCULATED DISPLAY ARRAY IS USED
              C     TO REFRESH THE SCREEN.
              C
0019                IF(DATA.AND..NOT.NEWD)GO TO 750
0020                IF(.NOT.DATA.AND..NOT.NEWR)GO TO 750
0021                IF(IAUX(11,ID).EQ.0)GO TO 750
              C
              C     CALCULATE NEW DISPLAY
              C
0022                INC=IAUX(11,ID)          !SAMPLE INTERVAL IN NANOSECONDS
0023                JNEAR=NEAR/INC+1         !ARRAY INDEX OF NEAR PICK
0024                JFAR=IFAR/INC+1          !ARRAY INDEX OF FAR PICK
              C
              C     MAKE SURE THE NEAR PICK IS SMALLEST, IN CASE AN ERROR HAS BEEN MADE
              C     SPECIFYING THE PICK POINTS.
              C
0025                KNEAR=MIN(JNEAR,JFAR)
0026                KFAR=MAX(JNEAR,JFAR)
              C
              C     ARRAY INDEXES OF ENDS OF PICK INTERVALS
              C
0027                KNEAR1=KNEAR+9
0028                KFAR1=KFAR+9
0029                SPLIT=.FALSE.
0030                I132=IHRES*132  !NUMBER OF DATA POINTS NEEDED TO FILL SCREEN
```

```
FORTRAN IV-PLUS V02-51E        09:18:59    27-FEB-81          PAGE 10
OMEG58.FTN        /TR:BLOCKS/WR

0031                 IF(IHRES.LT.16)GO TO 550
           C
           C         IF HORIZONTAL RESOLUTION IS 16, DISPLAY ALL DATA
           C
0032                 J=1
0033                 K=2048
0034                 GO TO 660         !FILL IN DISPLAY ARRAY
0035       550       IF(KNEAR.LT.2048)GOTO 570
           C
           C         IF BOTH PICK POINTS ARE TOO BIG, TAKE DISPLAY FROM THE TOP END OF
           C         THE DATA
           C
0036       560       K=2048
0037                 J=2049-I132
0038                 GOTO 660          !FILL IN DISPLAY ARRAY
0039       570       IF(KFAR.LT.2048)GOTO 580
           C
           C         IF THE FAR PICK POINT IS TOO BIG, THE DISPLAY WILL INCLUDE THE NEAR
           C         PICK INTERVAL AND AS MUCH OF THE TOP END OF THE DATA AS POSSIBLE
           C
0040                 IF(KNEAR+I132.GE.2048)GOTO 560
0041                 J=KNEAR
0042                 K=J+I132-1
0043                 GOTO 660          !FILL IN DISPLAY ARRAY
0044       580       IF(KFAR-KNEAR.GT.64*IHRES)GOTO 610
           C
           C         MAKE DISPLAY SYMMETRICAL ABOUT PICKS IF POSSIBLE.
           C
           C         DISPLAY WILL NOT BE SPLIT
           C
0045       590       IF(KFAR1.GE.2048)GOTO 560
           C
           C         NX IS THE NUMBER OF POINTS TO BE ADDED TO KFAR1 OR KNEAR TO FILL
           C         THE SCREEN
           C
0046                 NX=I132-KFAR1+KNEAR-1
0047                 IF(KFAR1+NX/2.GT.2048)GOTO 560
0048                 IF(KNEAR-NX+NX/2.GE.1)GOTO 600
           C
           C         THE DISPLAY WILL START AT THE BEGINNING OF THE DATA
           C
0049                 J=1
0050                 K=I132
0051                 GOTO 660          !FILL THE DISPLAY ARRAY
           C
           C         THE DISPLAY WILL BE SYMMETRICAL ABOUT THE PICK POINTS
           C
0052       600       K=KFAR1+NX/2
0053                 J=K+1-I132
0054                 GOTO 660          !FILL THE DISPLAY ARRAY
           C
           C         THE DISPLAY WILL BE SPLIT
           C
0055       610       NE=32*IHRES-5     !NUMBER OF POINTS TO ADD TO KNEAR AND KFAR1
0056                 NM=33*IHRES-5     !NUMBER OF POINTS TO ADD TO KNEAR1 AND KFAR
0057                 IF(KNEAR.GE.1+NE.AND.2048.GE.KFAR1+NE)GOTO 650
```

```
                C
                C       ONE SIDE OF THE DISPLAY WON'T BE SYMMETRICAL
                C
 0058                   KK=MIN(KFAR1,2048)
                C
                C       IF THE FOLLOWING STATEMENT IS TRUE, THE DISPLAY WILL NOT BE SPLIT
                C
 0059                   IF(2*NE-KNEAR+1-2048+KK.GT.KFAR-KNEAR1-2*NM)GOTO 590
 0060                   SPLIT=.TRUE.
 0061                   IF(KNEAR.LT.1+NE)GOTO 620
                C
                C       THE LEFT HALF OF THE DISPLAY WILL BE SYMMETRICAL, THE RIGHT HALF
                C       WON'T BE
                C
 0062                   J=KNEAR-NE
 0063                   J1=KNEAR1+NM
 0064                   K=2048
 0065                   K1=KFAR-NM-NE+K-KFAR1
 0066                   GOTO 660          !FILL IN THE DISPLAY ARRAY
 0067           620     IF(2048.LT.KFAR1+NE)GOTO 640
                C
                C       THE RIGHT HALF OF THE DISPLAY WILL BE SYMMETRICAL, THE LEFT HALF
                C       WON'T BE
                C
 0068                   K=KFAR1+NE
 0069                   K1=KFAR-NM
 0070           630     J=1
 0071                   J1=KNEAR1+NM+NE-KNEAR+J
 0072                   GOTO 660          !FILL IN THE DISPLAY ARRAY
                C
                C       NEITHER HALF OF THE DISPLAY WILL BE SYMMETRICAL
                C
 0073           640     K=2048
 0074                   K1=KFAR-NM-NE+K-KFAR1
 0075                   GOTO 630
                C
                C       BOTH HALVES OF THE DISPLAY WILL BE SYMMETRICAL
                C
 0076           650     SPLIT=.TRUE.
 0077                   J=KNEAR-NE
 0078                   J1=KNEAR1+NM
 0079                   K1=KFAR-NM
 0080                   K=KFAR1+NE
                C
                C       FILL IN DISPLAY ARRAY
                C
 0081           660     INDEX=J
 0082                   IF(KNEAR.GE.J.AND.KNEAR.LE.K)INDEX=KNEAR
 0083                   CALL NORM(INDEX,ID)      !FIND NORMALIZING FACTOR
 0084                   JK=J
 0085                   IF(SPLIT)GO TO 690
                C
                C       UNDIVIDED DISPLAY CALCULATION
                C
 0086                   DO 680 I=1,132
 0087                   RSUM=0.0
```

```
              DO 670 L=1,IHRES
              CALL CALC(JK,ID,R)
              JK=JK+1
              RSUM=RSUM+R
        670   CONTINUE
              CALL CHECK(RSUM/IHRES,IDISP(I,ID))
              IF(JK.GT.K)GO TO 730
        680   CONTINUE
              GO TO 730
      C
      C       SPLIT SCREEN CALCULATION
      C
        690   IDISP(66,ID)=0
              IDISP(67,ID)=0
              DO 720 M=0,130,67
              DO 710 I=1,65
              RSUM=0.0
              DO 700 L=1,IHRES
              CALL CALC(JK,ID,R)
              JK=JK+1
              RSUM=RSUM+R
        700   CONTINUE
              CALL CHECK(RSUM/IHRES,IDISP(M+I,ID))
              IF(JK.GT.K)GO TO 730
        710   CONTINUE
              JK=K1
        720   CONTINUE
      C
      C       COMPRESS DATA IN THE VERTICAL TO FIT THE SCREEN
      C
        730   IOFF=(4-IVRES)*33
              DO 740 I=1,132
              IDISP(I,ID)=(IDISP(I,ID)-IOFF)/IVRES
        740   CONTINUE
      C
      C       TRANSFER CALCULATED ARRAY TO THE SCREEN
      C
        750   IF(VT100)GO TO 760
      C
      C       SET ANSI MODE
      C
              WRITE(5,2230)ESC
      C
      C       SET 132 COLUMNS
      C
              WRITE(5,2240)ESC,"150
      C
      C       SET SPECIAL GRAPHICS SET
      C
              WRITE(5,2250)ESC
              VT100=.TRUE.
              DISP=.TRUE.
      C
      C       ERASE THE SCREEN
      C
        760   WRITE(5,2255)ESC
```

```
0123              JK=J
0124              IF(SPLIT)GO TO 780
0125              DO 770 I=1,132
           C
           C      THE FOLLOWING TWO STATEMENTS PLOT THE DATA IN THE PICK INTERVALS
           C      IN REVERSE VIDEO.  (BLACK ON WHITE)
           C
0126              IF(KNEAR.LT.JK+IHRES.AND.KNEAR1.GE.JK)WRITE(5,2260)ESC,"155
0127              IF(KFAR.LT.JK+IHRES.AND.KFAR1.GE.JK)WRITE(5,2260)ESC,"155
0128              IP=64-IDISP(I,ID)
0129              IF(IP.LT.0)IP=0
0130              IF(IP.GT.64)IP=64
0131              IL=IP/5+1                !LINE TO PLOT ON
0132              IC=MOD(IP,5)+"157        !BAR CODE TO PLOT
0133              CALL DSPLAY(IL,I,IC)
0134              WRITE(5,2270)ESC,"155    !TURN OFF REVERSE VIDEO
0135              JK=JK+IHRES
0136              IF(JK.GT.K)GO TO 830
0137       770    CONTINUE
0138              GO TO 830
0139       780    DO 800 M=0,130,67
0140              DO 790 I=1,65
           C
           C      THE FOLLOWING TWO STATEMENTS PLOT THE DATA IN THE PICK INTERVALS
           C      IN REVERSE VIDEO.  (BLACK ON WHITE)
           C
0141              IF(KNEAR.LT.JK+IHRES.AND.KNEAR1.GE.JK)WRITE(5,2260)ESC,"155
0142              IF(KFAR.LT.JK+IHRES.AND.KFAR1.GE.JK)WRITE(5,2260)ESC,"155
0143              IP=64-IDISP(M+I,ID)
0144              IF(IP.LT.0)IP=0
0145              IF(IP.GT.64)IP=64
0146              IL=IP/5+1                !LINE TO PLOT ON
0147              IC=MOD(IP,5)+"157        !BAR CODE TO PLOT
0148              CALL DSPLAY(IL,I+M,IC)
0149              WRITE(5,2270)ESC,"155    !TURN OFF REVERSE VIDEO
0150              JK=JK+IHRES
0151              IF(JK.GT.K)GO TO 810
0152       790    CONTINUE
0153              JK=K1
0154       800    CONTINUE
           C
           C      DRAW DOUBLE LINE TO SEPERATE THE TWO HALVES OF THE DISPLAY
           C
0155       810    DO 820 I=1,13
0156              CALL DSPLAY(I,66,"170)
0157              CALL DSPLAY(I,67,"170)
0158       820    CONTINUE
0159       830    IF(DATA)NEWD=.FALSE.
0160              IF(.NOT.DATA)NEWR=.FALSE.
0161              SCREEN=.FALSE.
           C
           C      WRITE THE FILE NUMBER IN THE UPPER LEFT CORNER
           C
0162              WRITE(5,2275)ESC,IAUX(7,ID)
0163              IF(DATA)RETURN
           C
```

```
      C       WRITE "REF" BELOW THE FILE NUMBER IF THIS IS THE REFERENCE SHOT
      C
              WRITE(5,2280)ESC
              RETURN
      2230    FORMAT(1H+,A1,'<')
      2240    FORMAT(1H+,A1,'[?3',A1)
      2250    FORMAT(1H+,A1,'(0')
      2255    FORMAT(1H+,A1,'[2J')
      2260    FORMAT(1H+,A1,'[7',A1)
      2270    FORMAT(1H+,A1,'[0',A1)
      2275    FORMAT(1H+,A1,'[1;1H',I4)
      2280    FORMAT(1H+,A1,'[2;1H','REF')
              END
```

```
FORTRAN IV-PLUS V02-51E          09:18:59    27-FEB-81          PAGE 15
OMEG5B.FTN          /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                      ATTRIBUTES

   1    $CODE1   004220  1096                RW,I,CON,LCL
   2    $PDATA   000024    10                RW,D,CON,LCL
   3    $IDATA   000242    81                RW,D,CON,LCL
   4    $VARS    000054    22                RW,D,CON,LCL
   5    $TEMPS   000004     2                RW,D,CON,LCL
   6    .$$$$.   000002     1                RW,D,OVR,GBL
   7    TFLAGS   000006     3                RW,D,OVR,GBL
   8    AUXIL    000470   156                RW,D,OVR,GBL
   9    PICKS    000010     4                RW,D,OVR,GBL
  10    PICK2    000006     3                RW,D,OVR,GBL
  11    RESD     000004     2                RW,D,OVR,GBL
  12    IDSPL    001034   270                RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DISPLA       1-000000   DSP          1-000072

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AUTO   L*1   9-000004   DATA   L*1   7-000002   DISP   L*1  12-001032   ESC    L*1   4-000000   I      I*2   4-000026
 IC     I*2   4-000052   ID     I*2   7-000000   IFAR   I*2   9-000002   IHRES  I*2  11-000000   IL     I*2   4-000050
 INC    I*2  10-000000   INDEX  I*2   4-000022   IOFF   I*2   4-000044   IP     I*2   4-000046   IVRES  I*2  11-000002
 I132   I*2   4-000006   J      I*2  12-001020   JFAR   I*2   4-000004   JK     I*2   4-000024   JNEAR  I*2   4-000002
 J1     I*2   4-000020   K      I*2  12-001022   KFAR   I*2  10-000004   KFAR1  I*2  12-001030   KK     I*2   4-000016
 KNEAR  I*2  10-000002   KNEAR1 I*2  12-001026   K1     I*2  12-001024   L      I*2   4-000034   M      I*2   4-000042
 NE     I*2   4-000012   NEAR   I*2   9-000000   NEWD   L*1   7-000004   NEWR   L*1   7-000005   NM     I*2   4-000014
 NX     I*2   4-000010   PLUME  L*1   9-000006   R      R*4   4-000036   RESID  L*1   9-000005   RSUM   R*4   4-000030
 SCREEN L*1   7-000003   SPLIT  L*1  12-001033   VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS        SIZE           DIMENSIONS

 IAUX   I*2   8-000000   000470    156      (52,3)
 IDISP  I*2  12-000000   001020    264      (132,2)

LABELS

 LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS

 540      1-000104        550      1-000404        560      1-000422        570      1-000456        580      1-000542
 590      1-000574        600      1-000716        610      1-000764        620      1-001250        630      1-001314
 640      1-001362        650      1-001430        660      1-001524        670         **           680         **
 690      1-002034        700         **           710         **           720         **           730      1-002346
```

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FORTRAN IV-PLUS V02-51E              09:18:59    27-FEB-81           PAGE 16
OMEG5B.FTN        /TR:BLOCKS/WR

 740        **           750    1-002470      760    1-002640      770        **          780    1-003316
 790        **           800       **         810    1-003770      820        **          830    1-004046
 2230'   3-000000        2240'  3-000010      2250'  3-000024      2255'   3-000036       2260'  3-000050
 2270'   3-000064        2275'  3-000100      2280'  3-000116

FUNCTIONS AND SUBROUTINES REFERENCED

 CALC      CHECK     DSPLAY   ERLINE   NORM      $MAXO      $MINO

TOTAL SPACE ALLOCATED = 006344  1650
```

```
0001                  SUBROUTINE RC
              C
              C       CALCULATE AND TYPE RN AND RF
              C
0002                  BYTE VT100,REF,NEWO,RNRF,AUTO,RESID,PLUME
0003                  COMMON VT100
0004                  COMMON /AUXIL/IAUX(52,3)
0005                  COMMON /RFLAG/RNRF
0006                  COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,
                      1OP,OPSIG,OPC
0007                  COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
0008                  COMMON /PICK2/INC,KNEAR,KFAR
0009                  IF(VT100)CALL ERLINE
0010                  IF(IAUX(7,2).NE.0)GOTO 870
0011                  WRITE(5,2320)   !THERE IS NO REFERENCE SHOT
0012                  RETURN
0013          870     IF(RNRF)GOTO 875
              C
              C       NEW RN AND RF MUST BE CALCULATED
              C
0014                  INC=IAUX(11,2)
0015                  KNEAR=MIN(NEAR,IFAR)/INC+1
0016                  KFAR=MAX(NEAR,IFAR)/INC+1
0017                  CALL NORM(KNEAR,2)
0018                  CALL PONDER(KNEAR,2,RN,RSIGN)
0019                  CALL PONDER(KFAR,2,RF,RSIGF)
0020                  RNRF=.TRUE.
              C
              C       RN AND RF HAVE BEEN CALCULATED
              C
0021          875     KNN=(KNEAR-1)*INC
0022                  KFF=(KFAR-1)*INC
0023                  IF(VT100)GOTO 880
0024                  WRITE(5,2330)(IAUX(I,2),I=1,7),KNN,RN,RSIGN,KFF,RF,
                      1RSIGF
0025                  RETURN
0026          880     WRITE(5,2340)(IAUX(I,2),I=1,7),KNN,RN,"147,RSIGN,KFF,
                      1RF,"147,RSIGF
0027                  RETURN
0028          2320    FORMAT(17X,'THERE IS NO REFERENCE SHOT.')
0029          2330    FORMAT(I3,'/',I2,'/',I2,I5,':',I2,':',I2,3X,'FILE',I5/
                      1' TN=',I5,'  RN=',F6.1,' +OR- ',F4.1/
                      2' TF=',I5,'  RF=',F6.1,' +OR- ',F4.1/)
0030          2340    FORMAT(17X,I2,'/',I2,'/',I2,I4,':',I2,':',I2,'  FILE',I5,3X,
                      1'TN=',I5,'  RN=',F6.1,A1,F4.1,'   TF=',I5,'  RF=',F6.1,A1,F4.1)
0031                  END
```

```
FORTRAN IV-PLUS V02-51E          09:19:10     27-FEB-81          PAGE 18
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1     $CODE1   000620   200             RW,I,CON,LCL
   2     $PDATA   000006     3             RW,D,CON,LCL
   3     $IDATA   000360   120             RW,D,CON,LCL
   4     $VARS    000006     3             RW,D,CON,LCL
   6     .$$$$.   000002     1             RW,D,OVR,GBL
   7     AUXIL    000470   156             RW,D,OVR,GBL
   8     RFLAG    000002     1             RW,D,OVR,GBL
   9     ACC2     000056    23             RW,D,OVR,GBL
  10     PICKS    000010     4             RW,D,OVR,GBL
  11     PICK2    000006     3             RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 RC           1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AUTO   L*1  10-000004   DF     R*4   9-000032   DN     R*4   9-000022   DSIGF  R*4   9-000036   DSIGN  R*4   9-000026
 I      I*2   4-000004   IFAR   I*2  10-000002   INC    I*2  11-000000   KFAR   I*2  11-000004   KFF    I*2   4-000002
 KNEAR  I*2  11-000002   KNN    I*2   4-000000   NEAR   I*2  10-000000   NEWD   L*1   9-000001   OP     R*4   9-000042
 OPC    R*4   9-000052   OPSIG  R*4   9-000046   PLUME  L*1  10-000006   REF    L*1   9-000000   RESID  L*1  10-000005
 RF     R*4   9-000012   RN     R*4   9-000002   RNRF   L*1   8-000000   RSIGF  R*4   9-000016   RSIGN  R*4   9-000006
 VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS        SIZE       DIMENSIONS

 IAUX   I*2   7-000000  000470   156    (52,3)

LABELS

 LABEL  ADDRESS      LABEL  ADDRESS      LABEL  ADDRESS      LABEL  ADDRESS      LABEL  ADDRESS

 870    1-000066     875    1-000222     880    1-000432     2320'  3-000000     2330'  3-000040
 2340'  3-000174

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  NORM    PONDER  $MAXO   $MINO

TOTAL SPACE ALLOCATED = 002004   514
```

```
FORTRAN IV-PLUS V02-51E        09:19:10    27-FEB-81          PAGE 19
OMEG5B.FTN       /TR:BLOCKS/WR

NO FPP INSTRUCTIONS GENERATED
```

```
            SUBROUTINE OPAC
C
C           CALCULATE AND DISPLAY OPACITY
C
            BYTE VT100,REF,NEWO,RNRF,DCR,AUTO,RESID,PLUME
            REAL*8 DOUBLE,DOUBL1
            COMMON VT100
            COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,
            1OP,OPSIG,OPC
            COMMON /AUXIL/IAUX(52,3)
            COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
            COMMON /PICK2/INC,KNEAR,KFAR
            COMMON /RFLAG/RNRF
            COMMON /STACK/NPLUM,NSTK,ELSTK,AZSTK
            DIMENSION SCR(20)
            DATA PI180/.017453293/
            IF(VT100)CALL ERLINE
            IF(IAUX(7,1).NE.0)GOTO 900
            WRITE(5,2350)    !THERE IS NO DATA ARRAY
            RETURN
900         INC=IAUX(11,1)
            KNEAR=MIN(NEAR,IFAR)/INC+1
            KFAR=MAX(NEAR,IFAR)/INC+1
C
C           THE FOLLOWING THREE STATEMENTS DETERMINE WHETHER RN AND RF MUST BE
C           RECALCULATED.
C
            IF(.NOT.REF)GOTO 910
            IF(IAUX(7,2).EQ.0)GOTO 910
            IF(RNRF)GOTO 910
C
C           CALCULATE RN, RF, AND THEIR STANDARD DEVIATIONS.
C
            CALL NORM(KNEAR,2)
            CALL PONDER(KNEAR,2,RN,RSIGN)
            CALL PONDER(KFAR,2,RF,RSIGF)
            RNRF=.TRUE.
C
C           CALCULATE DN, DF, AND THEIR STANDARD DEVIATIONS.
C
910         CALL NORM(KNEAR,1)
            CALL PONDER(KNEAR,1,DN,DSIGN)
            CALL PONDER(KFAR,1,DF,DSIGF)
            A1=DN+1E-15
            A2=DF+1E-15
            IF(A2.LE.1E-15)A2=1E-15
            A3=RN+1E-15
            A4=RF+1E-15
            IF(REF.AND.IAUX(7,2).NE.0)GOTO 920
            A3=1.0
            A4=1.0
C
C           CALCULATE THE OPACITY
C
920         OP=100.0*(1.0-SQRT(ABS(A2*A3/(A1*A4))))
            B1=DSIGN
```

```
0040                B2=DSIGF
0041                B3=RSIGN
0042                B4=RSIGF
0043                IF(REF.AND.IAUX(7,2).NE.0)GOTO 930
0044                B3=0.0
0045                B4=0.0
              C
              C     CALCULATE SO
              C
0046          930   OPSIG=50.0*SQRT(ABS(A3*A2/(A4*A1))*(B1**2/A1**2+B2**2/A2**2+
                   1B3**2/A3**2+B4**2/A4**2))
0047                IF(OPSIG.GT.99.0)OPSIG=99.0
              C
              C     ANGLE CORRECTIONS TO CALCULATED OPACITY
              C
0048                OPC=OP
0049                IF(ELSTK.EQ.0.0.AND.AZSTK.EQ.0.0.AND.IAUX(19,1).EQ.0.AND.
                   1IAUX(20,1).EQ.0)GOTO 1030
0050                IF(RESID)GOTO 1010
0051                EL=PI180*IAUX(20,1)/10.0
0052                OPC=100.0*(1.0-(1.0-OP/100.)**COS(EL))
0053                GOTO 1030
0054          1010  IF(PLUME)GOTO 1025
0055                CALL SEARCH(NPLUM,NP1,NP2)
0056                IF(NP1.GT.0)GOTO 1020
0057                IF(VT100)CALL ERLINE
0058                WRITE(5,2440)
0059                CALL WAIT(1,2,IWSTAT)
0060                GOTO 1030
0061          1020  NPLUM=(NP1+NP2)/2
0062          1025  AZ=PI180*IAUX(19,1)/10.0
0063                EL=PI180*IAUX(20,1)/10.0
0064                RP=NPLUM
0065                RS=NSTK
0066                RA=SQRT(RP**2*COS(EL)**2+RS**2*COS(ELSTK)**2-2.0*RP*RS
                   1*COS(AZ-AZSTK)*COS(EL)*COS(ELSTK))
0067                RS=SQRT(RS**2*COS(ELSTK)**2+RP**2*SIN(EL)**2)
0068                EPS=ACOS((RP**2+RA**2-RS**2)/(2.0*RA*RP))
0069                OPC=100.0*(1.0-(1.0-OP/100.0)**SIN(EPS))
              C
              C     CHANGE OP AND OPSIG TO INTEGERS FOR DISPLAY
              C
0070          1030  ENCODE(19,2360,SCR)OP,OPSIG
0071                DECODE(19,2365,SCR)IOP,IOPSIG
0072                ENCODE(10,2420,SCR)OPC
0073                DECODE(10,2430,SCR)IOPC
              C
              C     CONVERT THE ACTUALLY USED NEAR AND FAR PICK POINTS TO NANOSECONDS
              C     FOR DISPLAY
              C
0074                KNN=(KNEAR-1)*INC
0075                KFF=(KFAR-1)*INC
0076                IF(VT100)GOTO 940
0077                DOUBLE='      '
0078                IF(IAUX(7,2).EQ.0.OR..NOT.REF)DOUBLE='NO REF'
0079                WRITE(5,2370)(IAUX(I,1),I=1,7),DOUBLE
```

```
                DOUBLE='        '
                DOUBL1='        '
                IF(OPSIG.GE.8.5)DOUBLE='STD DEV '
                IF(OPSIG.GE.8.5)DOUBL1='TOO BIG'
                WRITE(5,2390)KNN,DN,DSIGN,KFF,DF,DSIGF,IOP,IOPSIG
                1,DOUBLE,DOUBL1,IOPC
                GOTO 950
        940     DCR=' '
                IF(.NOT.REF.OR.IAUX(7,2).EQ.0)DCR='*'
                CH='    '
                IF(OPSIG.GE.8.5)CH=4H !!!
                CALL ERLINE
                WRITE(5,2410)(IAUX(I,1),I=1,7),DCR,KNN,DN,"147,DSIGN
                1,KFF,DF,"147,DSIGF,IOP,"147,IOPSIG,CH,IOPC
        950     NEWO=.TRUE.      !NEW OPACITY IS AVAILABLE FOR THE REPORT
                RETURN
        2350    FORMAT(17X,'THERE IS NO DATA ARRAY!')
        2360    FORMAT(1X,F9.0,F9.0)
        2365    FORMAT(I9,1X,I8)
        2370    FORMAT(I3,'/',I2,'/'I2,I4,':',I2,':',I2,2X,'FILE',I5,2X,A8)
        2390    FORMAT(' TN=',I5,'  XN=',F6.1,' +OR- ',F4.1/' TF=',I5,
                1'  XF=',F6.1,' +OR- ',F4.1/11X,'OP=',I3,'% +OR-',I3,2X,2A8
                2/10X,'OPC=',I3)
        2410    FORMAT(9X,I2,'/',I2,'/',I2,I3,':',I2,':',I2,'  FILE',I5,2X,A1,
                1'TN=',I5,' XN=',F6.1,A1,F4.1,'  TF=',I5,' XF=',F6.1,A1,F4.1,
                2 3X,'OP=',I3,'%',A1,I2,A4,' OPC=',I3,'%')
        2420    FORMAT(1X,F9.0)
        2430    FORMAT(I9,1X)
        2440    FORMAT(17X,'PLUME NOT FOUND.  NO CORRECTION MADE')
                END
```

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FORTRAN IV-PLUS V02-51E        09:19:13    27-FEB-81          PAGE 23
OMEG5B.FTN      /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                    ATTRIBUTES

  1      $CODE1   003162   825               RW,I,CON,LCL
  2      $PDATA   000066    27               RW,D,CON,LCL
  3      $IDATA   000640   208               RW,D,CON,LCL
  4      $VARS    000264    90               RW,D,CON,LCL
  5      $TEMPS   000020     8               RW,D,CON,LCL
  6      .$$$$.   000002     1               RW,D,OVR,GBL
  7      ACC2     000056    23               RW,D,OVR,GBL
  8      AUXIL    000470   156               RW,D,OVR,GBL
  9      PICKS    000010     4               RW,D,OVR,GBL
 10      PICK2    000006     3               RW,D,OVR,GBL
 11      RFLAG    000002     1               RW,D,OVR,GBL
 12      STACK    000014     6               RW,D,OVR,GBL


ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 OPAC          1-000000


VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AUTO    L*1    9-000004   AZ      R*4    4-000220   AZSTK   R*4   12-000010   A1      R*4    4-000146   A2      R*4    4-000152
 A3      R*4    4-000156   A4      R*4    4-000162   B1      R*4    4-000166   B2      R*4    4-000172   B3      R*4    4-000176
 B4      R*4    4-000202   CH      R*4    4-000260   DCR     L*1    4-000000   DF      R*4    7-000032   DN      R*4    7-000022
 DOUBLE  R*8    4-000002   DOUBL1  R*8    4-000012   DSIGF   R*4    7-000036   DSIGN   R*4    7-000026   .EL     R*4    4-000206
 ELSTK   R*4   12-000004   EPS     R*4    4-000240   I       I*2    4-000256   IFAR    I*2    9-000002   INC     I*2   10-000000
 IOP     I*2    4-000244   IOPC    I*2    4-000250   IOPSIG  I*2    4-000246   IWSTAT  I*2    4-000216   KFAR    I*2   10-000004
 KFF     I*2    4-000254   KNEAR   I*2   10-000002   KNN     I*2    4-000252   NEAR    I*2    9-000000   NEWD    L*1    7-000001
 NPLUM   I*2   12-000000   NP1     I*2    4-000212   NP2     I*2    4-000214   NSTK    I*2   12-000002   OP      R*4    7-000042
 OPC     R*4    7-000052   OPSIG   R*4    7-000046   PI180   R*4    4-000142   PLUME   L*1    9-000006   RA      R*4    4-000234
 REF     L*1    7-000000   RESID   L*1    9-000005   RF      R*4    7-000012   RN      R*4    7-000002   RNRF    L*1   11-000000
 RP      R*4    4-000224   RS      R*4    4-000230   RSIGF   R*4    7-000016   RSIGN   R*4    7-000006   VT100   L*1    6-000000


ARRAYS

 NAME    TYPE  ADDRESS       SIZE           DIMENSIONS

 IAUX    I*2   8-000000  000470    156      (52,3)
 SCR     R*4   4-000022  000120     40      (20)


LABELS

 LABEL     ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS          LABEL    ADDRESS

 900       1-000070         910      1-000240         920      1-000414         930      1-000560         940      1-002574
 950       1-003144         1010     1-001116         1020     1-001222         1025     1-001252         1030     1-001714
```

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FORTRAN IV-PLUS V02-51E         09:19:13    27-FEB-81          PAGE 24
OMEG58.FTN       /TR:BLOCKS/WR

 2350'   3-000000         2360'   3-000034         2365'   3-000044         2370'   3-000052         2390'   3-000116
 2410'   3-000256         2420'   3-000434         2430'   3-000442         2440'   3-000446

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  NORM    PONDER  SEARCH  WAIT    $ACOS   $COS    $MAXO   $MINO   $SIN    $SQRT

TOTAL SPACE ALLOCATED = 005220  1352
```

```
FORTRAN IV-PLUS V02-51E          09:19:21     27-FEB-81              PAGE 25
OMEG5B.FTN          /TR:BLOCKS/WR

                    SUBROUTINE DSPLAY(IL,I,IC)
              C
              C     THIS SUBROUTINE DISPLAYS CHARACTER IC AT ROW IL AND COLUMN
              C     I OF THE SCREEN.
              C
                    BYTE ESC
                    DATA ESC/"33/
                    IF(IL.LT.10.AND.I.LT.10)WRITE(5,10)ESC,IL,I,IC
                    IF(IL.GE.10.AND.I.LT.10)WRITE(5,20)ESC,IL,I,IC
                    IF(IL.LT.10.AND.I.GE.10.AND.I.LT.100)WRITE(5,30)ESC,IL,I,IC
                    IF(IL.GE.10.AND.I.GE.10.AND.I.LT.100)WRITE(5,40)ESC,IL,I,IC
                    IF(IL.LT.10.AND.I.GE.100)WRITE(5,50)ESC,IL,I,IC
                    IF(IL.GE.10.AND.I.GE.100)WRITE(5,60)ESC,IL,I,IC
                    RETURN
              10    FORMAT(1H+,A1,'[',I1,';',I1,'H',A1)
              20    FORMAT(1H+,A1,'[',I2,';',I1,'H',A1)
              30    FORMAT(1H+,A1,'[',I1,';',I2,'H',A1)
              40    FORMAT(1H+,A1,'[',I2,';',I2,'H',A1)
              50    FORMAT(1H+,A1,'[',I1,';',I3,'H',A1)
              60    FORMAT(1H+,A1,'[',I2,';',I3,'H',A1)
                    END
```

```
FORTRAN IV-PLUS V02-51E         09:19:21    27-FEB-81            PAGE 26
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE               ATTRIBUTES

  1     $CODE1  000644   210            RW,I,CON,LCL
  3     $IDATA  000154    54            RW,D,CON,LCL
  4     $VARS   000002     1            RW,D,CON,LCL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DSPLAY       1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 ESC    L*1   4-000000   I      I*2   F-000004*  IC     I*2   F-000006*  IL     I*2   F-000002*

LABELS

 LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS

 10'     3-000000        20'     3-000022        30'     3-000044        40'     3-000066        50'     3-000110
 60'     3-000132

TOTAL SPACE ALLOCATED = 001022   265

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        09:19:23    27-FEB-81          PAGE 27
OMEG56.FTN          /TR:BLOCKS/WR

                    SUBROUTINE NORM(INDEX,ID)
          C
          C         THIS SUBROUTINE CALCULATES THE NORMALIZING FACTOR FOR THE
          C         LIDAR DATA ARRAYS.
          C
          C         THE SUBROUTINE CALC IS THEN USED TO CALCULATE NORMALIZED DATA.
          C
                    BYTE VT100,COMP,T2
                    COMMON VT100
                    COMMON /AUXIL/IAUX(52,3)
                    COMMON /LDATA/IDAT(2048,2)
                    COMMON /NFLAGS/COMP,T2,ITO
                    COMMON /CALNOR/W,Z,INC
                    W=1.0    !SET NORMALIZING FACTOR TO ONE
          C
          C         IF DATA WILL NOT BE COMPENSATED, RETURN
          C
                    IF(.NOT.COMP)RETURN
                    INC=IAUX(11,ID) !BIOMATION SAMPLING INTERVAL
                    Z=0       !ZERO OFFSET IS 0.0.0
          C
          C         OFFSET IS ZERO FOR LOG DATA
          C
                    IF(IAUX(10,ID).EQ.'LO')GOTO 20
          C
          C         CALCULATE ZERO OFFSET FROM FIRST 10 DATA POINTS
          C
                    DO 10 I=1,10
                    Z=Z+IDAT(I,ID)
          10        CONTINUE
                    Z=Z/10
          C
          C         CALCULATE THE COMPENSATED VALUE INDICATED BY INDEX IN THE ARRAY ID
          C         USING A NORMALIZING FACTOR OF ONE
          C
          20        CALL CALC(INDEX,ID,R)
                    IF(R.LE.1E-20)R=160.0
                    W=160.0/R          !NORMALIZE TO 160.0
                    RETURN
                    END
```

```
FORTRAN IV-PLUS V02-51E          09:19:23    27-FEB-81          PAGE 28
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME         SIZE                ATTRIBUTES

   1     $CODE1  000276    95             RW,I,CON,LCL
   2     $PDATA  000004     2             RW,D,CON,LCL
   3     $IDATA  000010     4             RW,D,CON,LCL
   4     $VARS   000006     3             RW,D,CON,LCL
   6     .$$$$.  000002     1             RW,D,OVR,GBL
   7     AUXIL   000470   156             RW,D,OVR,GBL
   8     LDATA   020000  4096             RW,D,OVR,GBL
   9     NFLAGS  000004     2             RW,D,OVR,GBL
  10     CALNOR  000012     5             RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 NORM           1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 COMP    L*1    9-000000   I      I*2   4-000000    ID     I*2   F-000004*   INC    I*2   10-000010   INDEX  I*2   F-000002*
 ITO     I*2    9-000002   R      R*4   4-000002    T2     L*1   9-000001    VT100  L*1    6-000000   W      R*4  10-000000
 Z       R*4   10-000004

ARRAYS

 NAME    TYPE  ADDRESS         SIZE          DIMENSIONS

 IAUX    I*2   7-000000  000470   156        (52,3)
 IDAT    I*2   8-000000  020000  4096        (2048,2)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 10          **            20      1-000174

FUNCTIONS AND SUBROUTINES REFERENCED

 CALC

TOTAL SPACE ALLOCATED = 021030   4364
```

```
FORTRAN IV-PLUS V02-51E        09:19:25    27-FEB-81           PAGE 29
OMEG5D.FTN         /TR:BLOCKS/WR

0001                SUBROUTINE CALC(IN,ID,A)
            C
            C       THIS SUBROUTINE IS USED TO DETERMINE THE VALUE OF LIDAR DATA INDICATED
            C       BY 'IN' IN THE ARRAY ID, CORRECTED FOR ZERO OFFSET, RANGE SQUARED
            C       CORRECTION, IF ANY, LOG AMPLIFICATION, IF USED, AND GATES, IF USED.
            C
0002                BYTE COMP,T2,VT100
0003                COMMON VT100
0004                COMMON /AUXIL/IAUX(52,3)
0005                COMMON /LDATA/IDAT(2048,2)
0006                COMMON /NFLAGS/COMP,T2,ITO
0007                COMMON /CALNOR/W,Z,INC
0008                A=IDAT(IN,ID)
            C
            C       IF DATA WILL NOT BE COMPENSATED, RETURN THE RAW DATA.
            C
0009                IF(.NOT.COMP)RETURN
0010                A=A-Z   !SUBTRACT THE ZERO OFFSET
            C
            C       CORRECT FOR LOG AMPLIFICATION IF USED
            C
0011                IF(IAUX(10,ID).EQ.'LO')A=(8E-7)*1.046**A
            C
            C       CORRECT FOR GATE ATTENUATION IF ANY
            C
0012                E1=IAUX(15,ID)/100.0
0013                IG1=IAUX(13,ID)/INC+1
0014                NG1=IAUX(14,ID)/INC+1
0015                E2=IAUX(18,ID)/100.0
0016                IG2=IAUX(16,ID)/INC+1
0017                NG2=IAUX(17,ID)/INC+1
0018                IF(IN.GE.IG1.AND.IN.LE.NG1)A=A*10.0**E1
0019                IF(IN.GE.IG2.AND.IN.LE.NG2)A=A*10.0**E2
0020                IF(.NOT.T2)GOTO 30
            C
            C       CORRECT FOR RANGE-SQUARED FALLOFF IF INDICATED
            C
0021                T=IN-ITO/INC+1
0022                IF(IAUX(10,ID).NE.'T2')A=A*T**2
0023        30      A=A*W   !NORMALIZE
0024                RETURN
0025                END
```

```
FORTRAN IV-PLUS V02-51E          09:19:25    27-FEB-81          PAGE 30
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME         SIZE                   ATTRIBUTES

  1     $CODE1   000556    183               RW,I,CON,LCL
  2     $PDATA   000010      4               RW,D,CON,LCL
  4     $VARS    000024     10               RW,D,CON,LCL
  6     .$$$$.   000002      1               RW,D,OVR,GBL
  7     AUXIL    000470    156               RW,D,OVR,GBL
  8     LDATA    020000   4096               RW,D,OVR,GBL
  9     NFLAGS   000004      2               RW,D,OVR,GBL
 10     CALNOR   000012      5               RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 CALC         1-000000

VARIABLES

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 A      R*4   F-000006*    COMP   L*1    9-000000    E1     R*4   4-000000     E2     R*4    4-000010    ID     I*2   F-000004*
 IG1    I*2   4-000004     IG2    I*2    4-000014    IN     I*2   F-000002*    INC    I*2   10-000010    ITO    I*2   9-000002
 NG1    I*2   4-000006     NG2    I*2    4-000016    T      R*4   4-000020     T2     L*1    9-000001    VT100  L*1   6-000000
 W      R*4  10-000000     Z      R*4   10-000004

ARRAYS

 NAME   TYPE  ADDRESS          SIZE          DIMENSIONS

 IAUX   I*2   7-000000  000470    156        (52,3)
 IDAT   I*2   8-000000  020000   4096        (2048,2)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 30      1-000530

TOTAL SPACE ALLOCATED = 021322  4457
```

```
FORTRAN IV-PLUS V02-51E         09:19:27    27-FEB-81           PAGE 31
OMEG5B.FTN          /TR:BLOCKS/WR

0001                SUBROUTINE PONDER(IN,ID,X,SIG)
          C
          C         THIS SUBROUTINE CALCULATES A 10-POINT AVERAGE AND STANDARD
          C         DEVIATION STARTING AT POINT (IN) IN THE ARRAY SELECTED BY ID.
          C
0002                RSUM=0.0
0003                RSUM2=0.0
0004                DO 10,I=IN,IN+9
0005                CALL CALC(I,ID,R)
0006                RSUM=RSUM+R
0007                RSUM2=RSUM2+R*R
0008      10        CONTINUE
0009                X=RSUM/10.0
0010                SIG=SQRT(ABS(RSUM2/9.0-X**2*10.0/9.0))
0011                RETURN
0012                END
```

```
FORTRAN IV-PLUS V02-51E          09:19:27    27-FEB-81          PAGE 32
OMEG5B.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                     ATTRIBUTES

  1     $CODE1  000234    78                  RW,I,CON,LCL
  3     $IDATA  000010     4                  RW,D,CON,LCL
  4     $VARS   000016     7                  RW,D,CON,LCL
  5     $TEMPS  000002     1                  RW,D,CON,LCL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 PONDER        1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 I       I*2   4-000010    ID     I*2   F-000004*   IN     I*2   F-000002*   R      R*4   4-000012    RSUM   R*4   4-000000
 RSUM2   R*4   4-000004    SIG    R*4   F-000010*   X      R*4   F-000006*

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 10          **

FUNCTIONS AND SUBROUTINES REFERENCED

 CALC     $SQRT

TOTAL SPACE ALLOCATED = 000264     90

SYO:[101,1]OMEG5B,SYO:[101,1]OMEG5B/-SP=SYO:[101,1]OMEG5B
```

```
FORTRAN IV-PLUS V02-51E        09:45:35    27-FEB-81          PAGE 1
OMEG5D.FTN        /TR:BLOCKS/WR

                  SUBROUTINE SOURCE
          C
          C       ENTRY POINT FOR SOURCE ROUTINE
          C       GET FILE NAME
          C
                  BYTE VT100
                  COMMON VT100
                  COMMON /RECORD/IRKD
                  DIMENSION ISFILE(9)
          70      IF(VT100)CALL ERLINE
                  WRITE(5,2010)
                  READ(5,2030)ISFILE
                  ISFILE(9)=0
          C
          C       IF FILE NAME IS BLANK, GO TO COMMAND INPUT
          C
                  IF(ISFILE(1).EQ.'  '.OR.ISFILE(1).EQ.'0 ')RETURN
          C
          C       OPEN THE SOURCE FILE
          C
                  CALL CLOSE(4)
                  OPEN(UNIT=4,NAME=ISFILE,TYPE='OLD',ACCESS='DIRECT',READONLY,
                  1ERR=100,SHARED,DISPOSE='SAVE',ASSOCIATEVARIABLE=IRKD)
          C
          C       INITIALIZE FILE POINTER
          C
                  CALL SRCRED(1,3,IERR,1)
                  RETURN
          C
          C       HERE IF ERROR OPENING FILE
          C
          100     IF(VT100)CALL ERLINE
                  WRITE(5,2040)
                  CALL WAIT(3,2,IWSTAT)
                  GOTO 70
          2010    FORMAT(1H$,16X,'ENTER INPUT FILE SPECIFICATION:  ')
          2030    FORMAT(20A2)
          2040    FORMAT(17X,'ERROR OPENING DISC FILE')
                  END
```

```
FORTRAN IV-PLUS V02-51E         09:45:35    27-FEB-81          PAGE 2
OMEG5D.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1    $CODE1  000266    91               RW,I,CON,LCL
   2    $PDATA  000020     8               RW,D,CON,LCL
   3    $IDATA  000216    71               RW,D,CON,LCL
   4    $VARS   000026    11               RW,D,CON,LCL
   6    .$$$$.  000002     1               RW,D,OVR,GBL
   7    RECORD  000002     1               RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 SOURCE       1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 IERR   I*2   4-000022    IRKD   I*2   7-000000    IWSTAT I*2   4-000024    VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS        SIZE         DIMENSIONS

 ISFILE I*2   4-000000  000022      9     (9)

LABELS

 LABEL   ADDRESS        LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS

 70      1-000014       100     1-000200        2010'   3-000000        2030'   3-000050        2040'   3-000054

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   ERLINE  OPEN$   SRCRED  WAIT

TOTAL SPACE ALLOCATED = 000556   183

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:45:38    27-FEB-81           PAGE 3
OMEG5D.FTN        /TR:BLOCKS/WR

0001                  SUBROUTINE REFER
            C
            C         REF ENTRY.  REFERENCE ARRAYS WILL BE USED FOR DISPLAY, ID, LIST.
            C
0002                  BYTE VT100, DATA, SCREEN, NEWD, NEWR
0003                  COMMON VT100
0004                  COMMON /TFLAGS/ID, DATA, SCREEN, NEWD, NEWR
0005                  IF(VT100)CALL ERLINE
0006                  IF(.NOT.DATA)RETURN      !GET NEW COMMAND
0007                  ID=2
0008                  DATA=.FALSE.
0009                  SCREEN=.TRUE.
0010                  RETURN
0011                  END
```

```
FORTRAN IV-PLUS V02-51E          09:45:38    27-FEB-81          PAGE 4
OMEG5D.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME       SIZE                  ATTRIBUTES

  1      $CODE1   000072    29            RW,I,CON,LCL
  3      $IDATA   000002     1            RW,D,CON,LCL
  6      .$$$$.   000002     1            RW,D,OVR,GBL
  7      TFLAGS   000006     3            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 REFER        1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DATA   L*1   7-000002   ID     I*2   7-000000   NEWD   L*1   7-000004   NEWR   L*1   7-000005   SCREEN L*1   7-000003
 VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000104    34

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E          09:45:39     27-FEB-81          PAGE 5
OMEG5D.FTN       /TR:BLOCKS/WR

0001                    SUBROUTINE DTA
              C
              C         DATA ENTRY.  DATA ARRAYS WILL BE USED FOR DISPLAY, ID, LIST.
              C
0002                    BYTE VT100,DATA,SCREEN,NEWD,NEWR
0003                    COMMON VT100
0004                    COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005                    IF(VT100)CALL ERLINE
0006                    IF(DATA)RETURN   !GET NEW COMMAND
0007                    DATA=.TRUE.
0008                    SCREEN=.TRUE.
0009                    ID=1
0010                    RETURN
0011                    END
```

```
FORTRAN IV-PLUS V02-51E          09:45:39    27-FEB-81          PAGE 6
OMEG5D.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                  ATTRIBUTES

  1      $CODE1   000072    29            RW,I,CON,LCL
  3      $IDATA   000002     1            RW,D,CON,LCL
  6      .$$$$.   000002     1            RW,D,OVR,GBL
  7      TFLAGS   000006     3            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DTA          1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DATA   L*1   7-000002   ID     I*2   7-000000   NEWD   L*1   7-000004   NEWR   L*1   7-000005   SCREEN L*1   7-000003
 VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000104    34

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E          09:45:40     27-FEB-81           PAGE 7
OMEGSD.FTN        /TR:BLOCKS/WR

0001                    SUBROUTINE RD
                C
                C       READ DATA FROM SOURCE FILE
                C
0002                    BYTE VT100,DATA,SCREEN,NEWD,NEWR
0003                    COMMON VT100
0004                    COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005                    COMMON /FNUM/IF
0006                    IF(VT100)CALL ERLINE
0007                    CALL SRCRED(IF,1,IERR,0)
0008                    IF(IERR.NE.0)RETURN         !GET NEW COMMAND
0009                    IF=IF+1
0010                    NEWD=.TRUE.
0011                    RETURN
0012                    END
```

```
FORTRAN IV-PLUS V02-51E          09:45:40    27-FEB-81          PAGE 8
OMEGSD.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1    $CODE1   000072    29              RW,I,CON,LCL
   2    $PDATA   000010     4              RW,D,CON,LCL
   3    $IDATA   000014     6              RW,D,CON,LCL
   4    $VARS    000002     1              RW,D,CON,LCL
   6    .$$$$.   000002     1              RW,D,OVR,GBL
   7    TFLAGS   000006     3              RW,D,OVR,GBL
   8    FNUM     000002     1              RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 RD           1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 DATA   L*1   7-000002    ID     I*2   7-000000    IERR   I*2   4-000000    IF     I*2   8-000000    NEWD   L*1   7-000004
 NEWR   L*1   7-000005    SCREEN L*1   7-000003    VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  SRCRED

TOTAL SPACE ALLOCATED = 000132    45

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:45:41     27-FEB-81           PAGE 9
OMEGSD.FTN        /TR:BLOCKS/WR

0001              SUBROUTINE RR
            C
            C     READ REFERENCE FROM SOURCE FILE
            C
0002              BYTE VT100,DATA,SCREEN,NEWD,NEWR
0003              COMMON VT100
0004              COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005              COMMON /FNUM/IF
0006              IF(VT100)CALL ERLINE
0007              CALL SRCRED(IF,2,IERR,0)
0008              IF(IERR.NE.0)RETURN       !GET NEW COMMAND
0009              IF=IF+1
0010              NEWR=.TRUE.
0011              RETURN
0012              END
```

```
FORTRAN IV-PLUS V02-51E           09:45:41     27-FEB-81          PAGE 10
OMEG5D.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

  1     $CODE1   000072     29             RW,I,CON,LCL
  2     $PDATA   000010      4             RW,D,CON,LCL
  3     $IDATA   000014      6             RW,D,CON,LCL
  4     $VARS    000002      1             RW,D,CON,LCL
  6     .$$$$.   000002      1             RW,D,OVR,GBL
  7     TFLAGS   000006      3             RW,D,OVR,GBL
  8     FNUM     000002      1             RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 RR           1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 DATA   L*1   7-000002    ID     I*2   7-000000    IERR   I*2   4-000000    IF     I*2   8-000000    NEWD   L*1   7-000004
 NEWR   L*1   7-000005    SCREEN L*1   7-000003    VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  SRCRED

TOTAL SPACE ALLOCATED = 000132    45

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E          09:45:42    27-FEB-81           PAGE 11
OMEG5D.FTN        /TR:BLOCKS/WR

0001                SUBROUTINE FILE
            C
            C       GET LIDAR SHOT NUMBER
            C
0002                BYTE VT100
0003                COMMON VT100
0004                COMMON /FNUM/IF
0005        230     IF(VT100)CALL ERLINE
0006                WRITE(5,2130)
0007                READ(5,*)IF
000E                IF(IF.GT.0.AND.IF.LT.1851)RETURN
            C
            C       LIDAR SHOT NUMBER IS OUT OF RANGE, TRY AGAIN
            C
0009                IF(VT100)CALL ERLINE
0010                WRITE(5,2140)
0011                CALL WAIT(2,2,IWSTAT)
0012                GO TO 230
0013        2130    FORMAT(1H$,16X,'ENTER FILE NUMBER ')
0014        2140    FORMAT(' FILE NUMBER MUST BE BETWEEN 1 AND 1850')
0015                END
```

```
FORTRAN IV-PLUS V02-51E          09:45:42     27-FEB-81          PAGE 12
OMEG5D.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1     $CODE1    000174    62            RW,I,CON,LCL
   2     $PDATA    000004     2            RW,D,CON,LCL
   3     $IDATA    000116    39            RW,D,CON,LCL
   4     $VARS     000002     1            RW,D,CON,LCL
   6     .$$$$.    000002     1            RW,D,OVR,GBL
   7     FNUM      000002     1            RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS

 FILE           1-000000

VARIABLES

 NAME   TYPE   ADDRESS      NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS

 IF     I*2    7-000000     IWSTAT I*2    4-000000    VT100  L*1    6-000000

LABELS

 LABEL   ADDRESS            LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 230     1-000014           2130'   3-000000          2140'   3-000032

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  WAIT

TOTAL SPACE ALLOCATED = 000324   106

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        09:45:43     27-FEB-81          PAGE 13
OMEG5D.FTN      /TR:BLOCKS/WR

0001                 SUBROUTINE NO
          C
          C          NO REFERENCE USED IN CALCULATION
          C
0002                 BYTE VT100,NEWO,REF
0003                 COMMON VT100
0004                 COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,OP,
                     1OPSIG,OPC
0005                 IF(VT100)CALL ERLINE
0006                 REF=.FALSE.
0007                 RETURN
0008                 END
```

```
FORTRAN IV-PLUS V02-51E          09:45:43    27-FEB-81           PAGE 14
OMEG5D.FTN        /TR:BLOCKS/WR

PRCGRAM SECTIONS

NUMBER   NAME       SIZE                  ATTRIBUTES

  1      $CODE1   000044     18           RW,I,CON,LCL
  3      $IDATA   000002      1           RW,D,CON,LCL
  6      .$$$$.   000002      1           RW,D,OVR,GBL
  7      ACC2     000056     23           RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS

 ND            1-000000

VARIABLES

 NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS

 DF      R*4   7-000032   DN      R*4   7-000022   DSIGF   R*4   7-000036   DSIGN   R*4   7-000026   NEWD    L*1   7-000001
 OP      R*4   7-000042   OPC     R*4   7-000052   OPSIG   R*4   7-000046   REF     L*1   7-000000   RF      R*4   7-000012
 RN      R*4   7-000002   RSIGF   R*4   7-000016   RSIGN   R*4   7-000006   VT100   L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000126    43

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E          09:45:44     27-FEB-81            PAGE 15
OMEG5D.FTN        /TR:BLOCKS/WR

0001                   SUBROUTINE YES
              C
              C        REFERENCE WILL BE USED IN CALCULATION
              C
0002                   BYTE VT100,NEWO,REF
0003                   COMMON VT100
0004                   COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,OP
                       1,OPSIG,OPC
0005                   IF(VT100)CALL ERLINE
0006                   REF=.TRUE.
0007                   RETURN
0008                   END
```

```
FORTRAN IV-PLUS V02-51E          09:45:44    27-FEB-81           PAGE 16
OMEG5D.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                  ATTRIBUTES

  1     $CODE1   000046     19            RW,I,CON,LCL
  3     $IDATA   000002      1            RW,D,CON,LCL
  6     .$$$$.   000002      1            RW,D,OVR,GBL
  7     ACC2     000056     23            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 YES          1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DF     R*4   7-000032   DN     R*4   7-000022   DSIGF  R*4   7-000036   DSIGN  R*4   7-000026   NEWD   L*1   7-000001
 OP     R*4   7-000042   OPC    R*4   7-000052   OPSIG  R*4   7-000046   REF    L*1   7-000000   RF     R*4   7-000012
 RN     R*4   7-000002   RSIGF  R*4   7-000016   RSIGN  R*4   7-000006   VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000130    44

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        09:45:45     27-FEB-81           PAGE 17
OMEG5D.FTN          /TR:BLOCKS/WR

0001                SUBROUTINE TEE2
          C
          C         TOGGLE T2 FLAG, TYPE CURRENT STATE OF FLAG.
          C
0002                BYTE VT100,DATA,SCREEN,NEWD,NEWR,RNRF,T2,COMP
0003                COMMON VT100
0004                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005                COMMON /RFLAG/RNRF
0006                COMMON /NFLAGS/COMP,T2,ITO
0007                T2=.NOT.T2
0008                NEWD=.TRUE.
0009                NEWR=.TRUE.
0010                SCREEN=.TRUE.
0011                RNRF=.FALSE.
0012                IF (VT100)CALL ERLINE
0013                IF(T2)WRITE(5,2170)
0014                IF(.NOT.T2)WRITE(5,2180)
0015                CALL WAIT(1,2,IWSTAT)
0016                RETURN
0017      2170      FORMAT(17X,'T-SQUARED CORRECTION PERMITTED')
0018      2180      FORMAT(17X,'T-SQUARED CORRECTION SUPPRESSED')
0019                END
```

```
FORTRAN IV-PLUS V02-51E               09:45:43     27-FEB-81           PAGE 18
OMEG5D.FTN         /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1    $CODE1  000160     56           RW,I,CON,LCL
   2    $PDATA  000010      4           RW,D,CON,LCL
   3    $IDATA  000122     41           RW,D,CON,LCL
   4    $VARS   000002      1           RW,D,CON,LCL
   6    .$$$$.  000002      1           RW,D,OVR,GBL
   7    TFLAGS  000006      3           RW,D,OVR,GBL
   8    RFLAG   000002      1           RW,D,OVR,GBL
   9    NFLAGS  000004      2           RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 TEE2         1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 COMP   L*1   9-000000    DATA   L*1   7-000002    ID     I*2   7-000000    ITO    I*2   9-000002    IWSTAT I*2   4-000000
 NEWD   L*1   7-000004    NEWR   L*1   7-000005    RNRF   L*1   8-000000    SCREEN L*1   7-000003    T2     L*1   9-000001
 VT100  L*1   6-000000

LABELS

 LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS

 2170'  3-000000          2180'  3-000044

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  WAIT

TOTAL SPACE ALLOCATED = 000332   109

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E          09:45:46    27-FEB-81           PAGE 19
OMEG5D.FTN       /TR:BLOCKS/WR

0001                SUBROUTINE COMPEN
            C
            C       TOGGLE COMP FLAG,  TYPE CURRENT STATE OF FLAG.
            C
0002                BYTE VT100,DATA,SCREEN,NEWD,NEWR,RNRF,COMP,T2
0003                COMMON VT100
0004                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005                COMMON /RFLAG/RNRF
0006                COMMON /NFLAGS/COMP,T2,ITO
0007                COMP=.NOT.COMP
0008                NEWD=.TRUE.
0009                NEWR=.TRUE.
0010                SCREEN=.TRUE.
0011                RNRF=.FALSE.
0012                IF(VT100)CALL ERLINE
0013                IF(COMP)WRITE(5,2190)
0014                IF(.NOT.COMP)WRITE(5,2200)
0015                CALL WAIT(1,2,IWSTAT)
0016                RETURN
0017        2190    FORMAT(17X,'DATA COMPENSATION WILL BE PERFORMED')
0018        2200    FORMAT(17X,'DATA WILL NOT BE COMPENSATED')
0019                END
```

```
FORTRAN IV-PLUS V02-51E          09:45:46    27-FEB-81          PAGE 20
OMEGSD.FTN      /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                 ATTRIBUTES

  1     $CODE1   000160    56            RW,I,CON,LCL
  2     $PDATA   000010     4            RW,D,CON,LCL
  3     $IDATA   000124    42            RW,D,CON,LCL
  4     $VARS    000002     1            RW,D,CON,LCL
  6      .$$$$.  000002     1            RW,D,OVR,GBL
  7     TFLAGS   000006     3            RW,D,OVR,GBL
  8     RFLAG    000002     1            RW,D,OVR,GBL
  9     NFLAGS   000004     2            RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS

 COMPEN        1-000000

VARIABLES

 NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS      NAME    TYPE  ADDRESS

 COMP    L*1   9-000000     DATA    L*1   7-000002     ID      I*2   7-000000     ITO     I*2   9-000002     IWSTAT  I*2   4-000000
 NEWD    L*1   7-000004     NEWR    L*1   7-000005     RNRF    L*1   8-000000     SCREEN  L*1   7-000003     T2      L*1   9-000001
 VT100   L*1   6-000000

LABELS

 LABEL   ADDRESS            LABEL   ADDRESS            LABEL   ADDRESS            LABEL   ADDRESS            LABEL   ADDRESS

 2190'   3-000000           2200'   3-000050

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  WAIT

TOTAL SPACE ALLOCATED = 000334    110

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:45:48    27-FEB-81           PAGE 21
OMEG5D.FTN         /TR:BLOCKS/WR

0001                SUBROUTINE TO
              C
              C     GET NEW TO VALUE
              C
0002                BYTE VT100,DATA,SCREEN,NEWD,NEWR,RNRF,COMP,T2
0003                COMMON VT100
0004                COMMON /AUXIL/IAUX(52,3)
0005                COMMON /LDATA/IDAT(2048,2)
0006                COMMON /STACK/NPLUM,NSTK,ELSTK,AZSTK
0007                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0008                COMMON /RFLAG/RNRF
0009                COMMON /NFLAGS/COMP,T2,ITO
0010                DATA PI180/.017453293/
0011                IF(VT100)CALL ERLINE
0012                WRITE(5,2230)
0013                READ(5,2080)IC
0014                IF(IC.EQ.'Y '.OR.IC.EQ.'YE')GOTO 10
0015                IF(VT100)CALL ERLINE
0016                WRITE(5,2210)ITO
0017                READ(5,2080)IC
0018                IF(IC.NE.'Y '.AND.IC.NE.'YE')RETURN
0019                IF(VT100)CALL ERLINE
0020                WRITE(5,2220)
0021                READ(5,*)ITO
0022          5     NEWD=.TRUE.
0023                NEWR=.TRUE.
0024                SCREEN=.TRUE.
0025                RNRF=.FALSE.
0026                RETURN
0027          10    DO 20 I=30,200
0028                IF(IDAT(I,1).EQ.255)GOTO 30
0029          20    CONTINUE
0030          25    ITO=710
0031                IF(VT100)CALL ERLINE
0032                WRITE(5,2240)
0033                GOTO 5
0034          30    IF(IDAT(I-1,1).GE.IDAT(I,1))GOTO 40
0035                I=I-1
0036                GOTO 30
0037          40    INC=IAUX(11,1)
0038                ITO=I*INC
0039                CALL SEARCH(NPLUM,NP1,NP2)
0040                IF(NP1.EQ.0)GOTO 25
0041                NP1=NP1/INC+1
0042          60    IF(IDAT(NP1-1,1).GE.IDAT(NP1,1))GOTO 70
0043                NP1=NP1-1
0044                GOTO 60
0045          70    NSTK=NP1*INC
0046                IF(VT100)CALL ERLINE
0047                DIST=(NSTK-ITO)*.1498962
0048                WRITE(5,2260)ITO,NSTK,DIST
0049                AZSTK=PI180*IAUX(19,1)/10.0
0050                ELSTK=PI180*IAUX(20,1)/10.0
0051                NPLUM=NSTK
0052                GOTO 5
0053          2080  FORMAT(A2)
```

```
0054     2210      FORMAT(1H$,16X,'TO IS NOW',I5,' NS.  DO YOU WANT TO CHANGE IT? ')
0055     2220      FORMAT(1H$,16X,'ENTER TO IN NANOSECONDS: ')
0056     2230      FORMAT(1H$,16X,'WILL TO BE LOCATED AUTOMATICALLY? ')
0057     2240      FORMAT(1H$,16X,'TO NOT FOUND, SET TO 710 NS')
0058     2260      FORMAT(1H$,16X,'TO IS',I5,' NANOSECONDS.  STACK IS AT',I6,
                   1' NANOSECONDS.  STACK DISTANCE IS',F6.0,' METERS.')
0059               END
```

```
FORTRAN IV-PLUS V02-51E          09:45:48    27-FEB-81          PAGE 23
OMEGSD.FTN          /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1     $CODE1   001102   289             RW,I,CON,LCL
   2     $PDATA   000004     2             RW,D,CON,LCL
   3     $IDATA   000412   133             RW,D,CON,LCL
   4     $VARS    000022     9             RW,D,CON,LCL
   6     .$$$$.   000002     1             RW,D,OVR,GBL
   7     AUXIL    000470   156             RW,D,OVR,GBL
   8     LDATA    020000  4096             RW,D,OVR,GBL
   9     STACK    000014     6             RW,D,OVR,GBL
  10     TFLAGS   000006     3             RW,D,OVR,GBL
  11     RFLAG    000002     1             RW,D,OVR,GBL
  12     NFLAGS   000004     2             RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 TO           1-000000

VARIABLES

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 AZSTK  R*4    9-000010    COMP   L*1   12-000000    DATA   L*1   10-000002    DIST   R*4    4-000016    ELSTK  R*4    9-000004
 I      I*2    4-000006    IC     I*2    4-000004    ID     I*2   10-000000    INC    I*2    4-000010    ITO    I*2   12-000002
 NEWD   L*1   10-000004    NEWR   L*1   10-000005    NPLUM  I*2    9-000000    NP1    I*2    4-000012    NP2    I*2    4-000014
 NSTK   I*2    9-000002    PI180  R*4    4-000000    RNRF   L*1   11-000000    SCREEN L*1   10-000003    T2     L*1   12-000001
 VT100  L*1    6-000000

ARRAYS

 NAME   TYPE  ADDRESS        SIZE          DIMENSIONS

 IAUX   I*2   7-000000   000470   156      (52,3)
 IDAT   I*2   8-000000   020000  4096      (2048,2)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 5       1-000332          10      1-000370          20        **              25      1-000444          30      1-000520
 40      1-000552          60      1-000640          70      1-000672          2080'   3-000000          2210'   3-000004
 2220'   3-000070          2230'   3-000130          2240'   3-000202          2260'   3-000244

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  SEARCH
```

```
FORTRAN IV-PLUS V02-51E          09:45:48    27-FEB-81          PAGE 24
OMEGSD.FTN       /TR:BLOCKS/WR

TOTAL SPACE ALLOCATED = 022264  4698
```

```
FORTRAN IV-PLUS V02-51E        09:45:51    27-FEB-81          PAGE 25
OMEG5D.FTN         /TR:BLOCKS/WR

0001               SUBROUTINE DL
          C
          C        SET DISPLAY LIMITS
          C
0002               BYTE VT100,DATA,SCREEN,NEWD,NEWR
0003               COMMON VT100
0004               COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005               COMMON /RESO/IHRES,IVRES
0006      840      IF(VT100)CALL ERLINE
0007               WRITE(5,2290)
0008               READ(5,*,ERR=840)IHRES
0009               IF(IHRES.LT.1)IHRES=1
0010               IF(IHRES.GT.16)IHRES=16
0011               GOTO 860
0012               ENTRY DY
0013      850      IF(VT100)CALL ERLINE
0014               WRITE(5,2300)
0015               READ(5,*,ERR=850)IVRES
0016               IF(IVRES.LT.1)IVRES=1
0017               IF(IVRES.GT.4)IVRES=4
0018      860      NEWD=.TRUE.
0019               NEWR=.TRUE.
0020               SCREEN=.TRUE.
0021               RETURN
0022      2290     FORMAT('$ENTER X DISPLAY RESOLUTION, DATA POINTS/DISPLAY'
                   1,' POINT:  ')
0023      2300     FORMAT('$ENTER Y DISPLAY RESOLUTION, DATA POINTS/DISPLAY'
                   1,' POINT:  ')
0024               END
```

```
FORTRAN IV-PLUS V02-51E         09:45:51    27-FEB-81          PAGE 26
OMEG5D.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

   1    $CODE1   000344   114              RW,I,CON,LCL
   3    $IDATA   000176    63              RW,D,CON,LCL
   6    .$$$$.   000002     1              RW,D,OVR,GBL
   7    TFLAGS   000006     3              RW,D,OVR,GBL
   8    RESO     000004     2              RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DL           1-000000   DY           1-000146

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DATA   L*1   7-000002   ID     I*2   7-000000   IHRES  I*2   8-000000   IVRES  I*2   8-000002   NEWD   L*1   7-000004
 NEWR   L*1   7-000005   SCREEN L*1   7-000003   VT100  L*1   6-000000

LABELS

 LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS        LABEL    ADDRESS

 840      1-000012       850      1-000160       860      1-000312       2290'    3-000000       2300'    3-000076

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000556   183

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:45:53    27-FEB-81           PAGE 27
OMEG5D.FTN       /TR:BLOCKS/WR

0001                    SUBROUTINE AVERAG
              C
              C         GET NEW AVERAGING INTERVAL
              C
0002                    BYTE VT100,AVE
0003                    COMMON VT100
0004                    COMMON /AVGE/SAVE,AVE
0005                    IF(VT100)CALL ERLINE
0006                    WRITE(5,2470)
0007                    READ(5,2080)IC
0008                    AVE=.FALSE.
0009                    IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 1065
0010                    IF(VT100)CALL ERLINE
0011                    WRITE(5,2460)
0012                    READ(5,*)SAVE
0013                    IF(SAVE.LT.0.0)SAVE=0.0
0014                    AVE=.TRUE.
0015          1065      RETURN
0016          2080      FORMAT(A2)
0017          2460      FORMAT(1H$,16X,'ENTER AVERAGING INTERVAL IN MINUTES: ')
0018          2470      FORMAT(1H$,16X,'SHOULD DATA BE AVERAGED? ')
0019                    END
```

```
FORTRAN IV-PLUS V02-51E          09:45:53    27-FEB-81          PAGE 28
OMEG5D.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                 ATTRIBUTES

  1      $CODE1   000242    81           RW,I,CON,LCL
  3      $IDATA   000122    41           RW,D,CON,LCL
  4      $VARS    000002     1           RW,D,CON,LCL
  6      .$$$$.   000002     1           RW,D,OVR,GBL
  7      AVGE     000006     3           RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AVERAG        1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AVE     L*1   7-000004    IC      I*2   4-000000    SAVE    R*4   7-000000    VT100   L*1   6-000000

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 1065    1-000240          2080'   3-000000          2460'   3-000004          2470'   3-000060

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000376   127
```

```
FORTRAN IV-PLUS V02-51E         09:45:54    27-FEB-81           PAGE 29
OMEG5D.FTN      /TR:BLOCKS/WR

0001                    SUBROUTINE EX
               C
               C        EXIT ROUTINE
               C
0002                    WRITE(5,2000)"33,"143   !RESET TERMINAL TO VT52 MODE
0003                    CALL WAIT(2,2,IWSTAT)
0004                    CALL EXIT
               C
               C        FORMAT STATEMENTS
               C
0005           2000     FORMAT('+',2A1)
0006                    END
```

```
FORTRAN IV-PLUS V02-51E          09:45:54    27-FEB-81           PAGE 30
OMEGSD.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1     $CODE1   000102     33            RW,I,CON,LCL
   2     $PDATA   000010      4            RW,D,CON,LCL
   3     $IDATA   000020      8            RW,D,CON,LCL
   4     $VARS    000002      1            RW,D,CON,LCL

ENTRY POINTS

 NAME     TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS

 EX              1-000000

VARIABLES

 NAME     TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS

 IWSTAT  I*2     4-000000

LABELS

 LABEL    ADDRESS            LABEL    ADDRESS           LABEL    ADDRESS           LABEL    ADDRESS           LABEL    ADDRESS

 2000'    3-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 EXIT     WAIT

TOTAL SPACE ALLOCATED = 000134    46

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:45:55     27-FEB-81           PAGE 31
OMEG5D.FTN       /TR:BLOCKS/WR

0001                  SUBROUTINE SRCRED(IF,JIN,IERR,JF)
            C
            C         THIS SUBROUTINE READS DATA FROM THE SOURCE FILE RECORD
            C         SELECTED BY IF AND READS IT INTO THE SET OF DATA ARRAYS
            C         SELECTED BY JIN.
            C
0002                  BYTE VT100
0003                  COMMON VT100
0004                  COMMON /AUXIL/IAUX(52,3)
0005                  COMMON /LDATA/IDAT(2048,2)
0006                  COMMON /RECORD/IRKD
0007                  IERR=0
            C
            C         IF JF IS 1, THE DIFFERENCE BETWEEN FILE NUMBER AND RECORD NUMBER,
            C         IF ANY, WILL BE DETERMINED.
            C
0008                  IF(JF.EQ.1)IOFF=0
0009                  NTIME=0
0010        10        J=IF-IOFF
0011                  IF(JIN.LT.3)GOTO 20
            C
            C         READ HEADER INFORMATION ONLY
            C
0012                  READ(4'J,ERR=30)(IAUX(K,JIN),K=1,52)
0013                  GOTO 25
            C
            C         READ HEADER INFORMATION AND LIDAR DATA BOTH
            C
0014        20        READ(4'J,ERR=30)(IAUX(K,JIN),K=1,52),(IDAT(K,JIN),K=1,2048)
            C
            C         IF THIS IS THE RIGHT SHOT, RETURN
            C
0015        25        IF(IAUX(20,JIN).EQ.990)IAUX(20,JIN)=99
0016                  IF(IAUX(7,JIN).EQ.IF)RETURN
            C
            C         RECALCULATE DIFFERENCE BETWEEN SHOT NUMBER AND RECORD NUMBER.
            C
0017                  IOFF=IAUX(7,JIN)-J
0018                  IF(JF.EQ.1)RETURN
0019                  NTIME=NTIME+1
            C
            C         TRY ONE MORE TIME
            C
0020                  IF(NTIME.EQ.1)GOTO 10
            C
            C         TWO TRIES AND STILL NO LUCK.  WRITE ERROR MESSAGE AND RETURN
            C
0021                  IERR=1
0022                  IF(VT100)CALL ERLINE
0023                  WRITE(5,1010)IF
0024                  RETURN
0025        30        IERR=1
0026                  IF(VT100)CALL ERLINE
0027                  WRITE(5,1030)
0028                  RETURN
0029        1010      FORMAT(17X,'COULD NOT FIND FILE ',I4)
```

```
0030      1030      FORMAT(17X,'ERROR READING SOURCE FILE')
0031                END
```

```
FORTRAN IV-PLUS V02-51E          09:45:55    27-FEB-81          PAGE 33
OMEG5D.FTN      /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1    $CODE1   000656   215              RW,I,CON,LCL
   3    $IDATA   000074    30              RW,D,CON,LCL
   4    $VARS    000010     4              RW,D,CON,LCL
   6    .$$$$.   000002     1              RW,D,OVR,GBL
   7    AUXIL    000470   156              RW,D,OVR,GBL
   8    LDATA    020000  4096              RW,D,OVR,GBL
   9    RECORD   000002     1              RW,D,OVR,GBL

ENTRY POINTS

 N4ME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 SRCRED       1-000000

VARIABLES

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 IERR   I*2   F-000006*    IF     I*2   F-000002*    IOFF   I*2   4-000000     IRKD   I*2   9-000000     J      I*2   4-000004
 JF     I*2   F-000010*    JIN    I*2   F-000004*    K      I*2   4-000006     NTIME  I*2   4-000002     VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS        SIZE          DIMENSIONS

 IAUX   I*2   7-000000  000470   156       (52,3)
 IDAT   I*2   8-000000  020000  4096       (2048,2)

LABELS

 LABEL    ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL.  ADDRESS

 10       1-000046         20      1-000212         25      1-000400         30      1-000576         1010'   3-000000
 1030'    3-000034

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 021456  4503

NO FPP INSTRUCTIONS GENERATED

SY0:[101,1]OMEG5D,SY0:[101,1]OMEG5D/-SP=SY0:[101,1]OMEG5D
```

```
FORTRAN IV-PLUS V02-51          09:02:06    04-SEP-80          PAGE 1
OMEG5E.FTN          /TR:BLOCKS/WR

0001                SUBROUTINE OLDFIL
            C
            C       GET OLD FILE NAME
            C
0002                BYTE LIST,OUT
0003                DIMENSION IRFILE(9)
0004                COMMON /AUXIL/IAUX(52,3)
0005                COMMON /REPORT/REP(14,136),IREP(12,136)
0006                COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
0007                COMMON /ACC1/ITCNT,STIM,SAVEC,NSIG,NAVE,OSIGSM,OPSUM
0008        340     WRITE(5,2090)
0009                READ(5,2030)IRFILE
0010                IRFILE(9)=0
0011                CALL CLOSE(2)
0012                OPEN(UNIT=2,NAME=IRFILE,TYPE='OLD',READONLY,ERR=350
                    1,DISPOSE='SAVE')
0013                GOTO 360
            C
            C       HERE IF ERROR OPENING FILE
            C
0014        350     WRITE(5,2040)
0015                GOTO 340
            C
            C       READ HEADER INFORMATION
            C
0016        360     READ(2,2050)(IAUX(I,3),I=1,52)
            C
            C       DISPLAY HEADER INFORMATION ON CRT
            C
0017                LIST=.FALSE.
0018                CALL FILIST(5,3,LIST)
            C
            C       READ DATA INTO REPORT ARRAYS
            C
0019                DO 370 I=1,136
0020                READ(2,2760,END=380)(IREP(L,I),L=1,12),(REP(L,I),L=1,14)
0021        370     CONTINUE
0022        380     CALL CLOSE(2)
0023                NOPAC=I-1
            C
            C       FIND FIRST SHOT OF PRINTED REPORT
            C
0024                IF(IREP(12,1).EQ.0)GOTO 410
0025                DO 390 I=1,NOPAC
0026                IF(IREP(12,I).LE.I)GOTO 400
0027        390     CONTINUE
0028                I=I-1
0029        400     NOPAC1=I+1
0030                IF(I.EQ.1)NOPAC1=1
            C
            C       FIND FIRST SHOT OF CURRENT RUNNING AVERAGE
            C
0031                ITCNT=1
0032                IF(NOPAC.GT.IREP(12,NOPAC))ITCNT=NOPAC-IREP(12,NOPAC)+1
            C
            C       GET START TIME OF CURRENT RUNNING AVERAGE
```

```
FORTRAN IV-PLUS V02-51          09:02:06    04-SEP-80           PAGE 2
OMEG5E.FTN        /TR:BLOCKS/WR

      C
                STIM=60.*IREP(4,ITCNT)+IREP(5,ITCNT)+IREP(6,ITCNT)/60.0
                SAVEC=REP(14,NOPAC)
                NSIG=IREP(12,NOPAC)
                NAVE=IREP(11,NOPAC)
                OSIGSM=NSIG*REP(13,NOPAC)
                OPSUM=NAVE*REP(12,NOPAC)
                NOPAC2=NOPAC-NOPAC1+1
                GOTO 420
      410       NOPAC1=1
                NOPAC2=1
                ITCNT=0
                NSIG=0
                NAVE=0
                SAVEC=0.0
                STIM=0.0
                OPSUM=0.0
                OSIGSM=0.0
      420       I=NOPAC
      C
      C         TYPE STATUS OF REPORT ARRAYS
      C
                WRITE(5,2160)IREP(7,I),IREP(8,I),NOPAC2,NOPAC
                RETURN
      2030      FORMAT(20A2)
      2040      FORMAT(17X,'ERROR OPENING DISC FILE')
      2050      FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
      2090      FORMAT('$ENTER SAVE FILE SPECIFICATION: ')
      2160      FORMAT(' FILE',I5,'  REF FILE',2I5,' SHOTS IN REPORT'
                1,I5,' SHOTS IN FILE.')
      2760      FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
                END
```

```
FORTRAN IV-PLUS V02-51          09:02:06    04-SEP-80          PAGE 3
OMEG5E.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                ATTRIBUTES

   1     $CODE1  001266   347            RW,I,CON,LCL
   2     $PDATA  000014     6            RW,D,CON,LCL
   3     $IDATA  000340   112            RW,D,CON,LCL
   4     $VARS   000030    12            RW,D,CON,LCL
   6     AUXIL   000470   156            RW,D,OVR,GBL
   7     REPORT  025200  5440            RW,D,OVR,GBL
   8     NPC     000010     4            RW,D,OVR,GBL
   9     ACC1    000026    11            RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 OLDFIL        1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 I       I*2   4-000024    ITCNT   I*2   9-000000    L       I*2   4-000026    LIST    L*1   4-000000    NAVE    I*2   9-000014
 NOPAC   I*2   8-000000    NOPAC1  I*2   8-000002    NOPAC2  I*2   8-000004    NSIG    I*2   9-000012    OPSUM   R*4   9-000022
 OSIGSM  R*4   9-000016    OUT     L*1   8-000006    SAVEC   R*4   9-000006    STIM    R*4   9-000002

ARRAYS

 NAME    TYPE  ADDRESS         SIZE          DIMENSIONS

 IAUX    I*2   6-000000  000470   156        (52,3)
 IREP    I*2   7-016700  006300  1632        (12,136)
 IRFILE  I*2   4-000002  000022     9        (9)
 REP     R*4   7-000000  016700  3808        (14,136)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 340     1-000014          350     1-000124          360     1-000154          370        **             380     1-000500
 390        **             400     1-000616          410     1-001074          420     1-001154          2030'   3-000000
 2040'   3-000004          2050'   3-000040          2090'   3-000076          2160'   3-000142          2760'   3-000240

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   FILIST  OPEN$

TOTAL SPACE ALLOCATED = 027620   6088
```

```
FORTRAN IV-PLUS V02-51          09:02:11    04-SEP-80        PAGE 4
OMEG5E.FTN         /TR:BLOCKS/WR

0001                SUBROUTINE IDENT
          C
          C         TYPE ID OF CURRENTLY SELECTED FILE.
          C
0002                BYTE LIST,DATA,SCREEN,NEWD,NEWR
0003                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0004                LIST=.FALSE.
0005                CALL FILIST(5,ID,LIST)
0006                RETURN
0007                END
```

```
FORTRAN IV-PLUS V02-51            09:02:11    04-SEP-80          PAGE 5
OMEG5E.FTN      /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

  1      $CODE1   000040     16            RW,I,CON,LCL
  2      $PDATA   000004      2            RW,D,CON,LCL
  3      $IDATA   000010      4            RW,D,CON,LCL
  4      $VARS    000002      1            RW,D,CON,LCL
  6      TFLAGS   000006      3            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 IDENT        1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 DATA   L*1   6-000002    ID     I*2   6-000000    LIST   L*1   4-000000    NEWD   L*1   6-000004    NEWR   L*1   6-000005
 SCREEN L*1   6-000003

FUNCTIONS AND SUBROUTINES REFERENCED

 FILIST

TOTAL SPACE ALLOCATED = 000064    26

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51          09:02:12     04-SEP-80          PAGE 6
OMEG5E.FTN         /TR:BLOCKS/WR

0001                SUBROUTINE LISTF
          C
          C         LIST CURRENT FILE ON THE LINE-PRINTER
          C
0002                BYTE LIST,VT100,DATA,SCREEN,NEWD,NEWR
0003                COMMON VT100
0004                COMMON /TFLAGS/ID,DATA,SCREEN,NEWD,NEWR
0005                IF(VT100)CALL ERLINE
0006                LIST=.TRUE.
0007                CALL FILIST(6,ID,LIST)
0008                CALL CLOSE(6)
0009                RETURN
0010                END
```

```
FORTRAN IV-PLUS V02-51          09:02:12    04-SEP-80          PAGE 7
OMEG5E.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

  1     $CODE1  000070     28              RW,I,CON,LCL
  2     $PDATA  000004      2              RW,D,CON,LCL
  3     $IDATA  000016      7              RW,D,CON,LCL
  4     $VARS   000002      1              RW,D,CON,LCL
  6     .$$$$.  000002      1              RW,D,OVR,GBL
  7     TFLAGS  000006      3              RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 LISTF        1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 DATA   L*1   7-000002   ID     I*2   7-000000   LIST   L*1   4-000000   NEWD   L*1   7-000004   NEWR   L*1   7-000005
 SCREEN L*1   7-000003   VT100  L*1   6-000000

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE    ERLINE   FILIST

TOTAL SPACE ALLOCATED = 000124    42

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51          09:02:13    04-SEP-80           PAGE 8
OMEG5E.FTN         /TR:BLOCKS/WR

0001                  SUBROUTINE FILIST(IU,JI,LIST)
            C
            C         THIS SUBROUTINE LISTS HEADER AND/OR LIDAR DATA ON THE
            C         TERMINAL OR LINE PRINTER.
            C
0002                  BYTE VT100,LIST
0003                  REAL*8 DOUBLE,DOUBL1
0004                  COMMON VT100
0005                  COMMON /AUXIL/IAUX(52,3)
0006                  COMMON /LDATA/IDAT(2048,2)
            C
            C         IF HEADER IS TO BE DISPLAYED ON THE TERMINAL, MAKE SURE IT IS IN
            C         VT52 MODE.
            C
0007                  IF(IU.EQ.5)WRITE(5,100)"33,"143
0008                  IF(IU.EQ.5)VT100=.FALSE.
0009                  IF(IU.EQ.5)CALL WAIT(2,2,IWSTAT)
0010                  WRITE(IU,200)IAUX(7,JI),(IAUX(I,JI),I=1,6),IAUX(8,JI),IAUX(9,JI)
0011                  WRITE(IU,300)(IAUX(I,JI),I=21,52)
0012                  DOUBLE='LOG CHAN'
0013                  DOUBL1='NEL'
0014                  ALPHA='    '
0015                  IF(IAUX(10,JI).EQ.'LI')DOUBLE='LINEAR C'
0016                  IF(IAUX(10,JI).EQ.'LI')DOUBL1='HANNEL'
0017                  IF(IAUX(10,JI).EQ.'T2')DOUBLE='T-SQUARE'
0018                  IF(IAUX(10,JI).EQ.'T2')DOUBL1='D CHANNE'
0019                  IF(IAUX(10,JI).EQ.'T2')ALPHA='L'
0020                  A=.001*IAUX(12,JI)
0021                  WRITE(IU,700)DOUBLE,DOUBL1,ALPHA,IAUX(11,JI),A
0022                  A=.1*IAUX(15,JI)
0023                  WRITE(IU,800)1,A,IAUX(13,JI),IAUX(14,JI)
0024                  A=.1*IAUX(18,JI)
0025                  WRITE(IU,800)2,A,IAUX(16,JI),IAUX(17,JI)
0026                  AZ=.1*IAUX(19,JI)
0027                  EL=.1*IAUX(20,JI)
0028                  WRITE(IU,900)AZ,EL
0029                  IF(IU.EQ.5.OR..NOT.LIST)RETURN
            C
            C         PRINT LIDAR DATA IF REQUESTED
            C
0030                  WRITE(6,1000)(I,I=0,190,10)
0031                  WRITE(6,1100)(10*J,(IDAT(J+I,JI),I=1,20),J=0,2020,20)
0032                  J=2040
0033                  WRITE(6,1200)10*J,(IDAT(J+I,JI),I=1,8)
0034                  RETURN
            C
            C         FORMATS
            C
0035        100       FORMAT(1H+,2A1)
0036        200       FORMAT('1FILE',I5,2X,I2,'/',I2,'/',I2,I4,':',I2,':',I2,2X,
                     1'REF. FILE',I5,2X,'GATE CALIBRATION FILE',I5/)
0037        300       FORMAT(1X,32A2/)
0038        700       FORMAT(1X,2A8,A4,I5,' NS/POINT',4X,'+OR-',F5.2,
                     1' VOLTS FULL SCALE')
0039        800       FORMAT(' GATE',I2,' ATTENUATION IS',F5.1,' DB.  STARTING AT'
                     1,I6,' NS, STOPPING AT',I6,' NS')
```

```
FORTRAN IV-PLUS V02-51          09:02:13    04-SEP-80            PAGE 9
OMEG5E.FTN       /TR:BLOCKS/WR

0040     900     FORMAT(/' AZIMUTH ANGLE',F6.1,', ELEVATION ANGLE',F5.1,//)
0041     1000    FORMAT(/' TIME(NS) ',20I5/)
0042     1100    FORMAT(I6,3X,20I5)
0043     1200    FORMAT(I6,3X,8I5/)
0044             END
```

```
FORTRAN IV-PLUS V02-51          09:02:13    04-SEP-80           PAGE 10
OMEG5E.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

   1     $CODE1   001526   427             RW,I,CON,LCL
   2     $PDATA   000112    37             RW,D,CON,LCL
   3     $IDATA   000460   152             RW,D,CON,LCL
   4     $VARS    000046    19             RW,D,CON,LCL
   6     .$$$$.   000002     1             RW,D,OVR,GBL
   7     AUXIL    000470   156             RW,D,OVR,GBL
   8     LDATA    020000  4096             RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 FILIST        1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 A       R*4   4-000030    ALPHA   R*4   4-000024    AZ      R*4   4-000034    DOUBLE  R*8   4-000000    DOUBL1  R*8   4-000010
 EL      R*4   4-000040    I       I*2   4-000022    IU      I*2   F-000002*   IWSTAT  I*2   4-000020    J       I*2   4-000044
 JI      I*2   F-000004*   LIST    L*1   F-000006*   VT100   L*1   6-000000

ARRAYS

 NAME    TYPE  ADDRESS      SIZE          DIMENSIONS

 IAUX    I*2   7-000000  000470   156     (52,3)
 IDAT    I*2   8-000000  020000  4096     (2048,2)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 100'    3-000000          200'    3-000006          300'    3-000122          700'    3-000130          800'    3-000212
 900'    3-000326          1000'   3-000404          1100'   3-000426          1200'   3-000436

FUNCTIONS AND SUBROUTINES REFERENCED

 WAIT

TOTAL SPACE ALLOCATED = 023060   4888

SY0:[101,1]OMEG5E,SY0:[101,1]OMEG5E/-SP=SY0:[101,1]OMEG5E
```

```
FORTRAN IV-PLUS V02-51          09:18:28    04-SEP-80           PAGE 1
OMEG5F.FTN       /TR:BLOCKS/WR

                 SUBROUTINE OUTP
         C
         C       SELECT NEW OUTPUT FILE
         C
                 BYTE VT100,OUT
                 COMMON VT100
                 COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
                 COMMON /OUTFIL/IOFILE(9)
         C       IS AN OUTPUT FILE ALREADY OPEN?
         C
                 IF(VT100)CALL ERLINE
                 IF(.NOT.OUT)GOTO 970
         C
         C       YES, TELL OPERATOR AND VERIFY NEED FOR NEW FILE.
         C
                 WRITE(5,2420)(IOFILE(I),I=1,7)
                 READ(5,2080)IC
                 IF(IC.NE.'Y '.AND.IC.NE.'YE')RETURN      !IF NO, GET NEXT COMMAND
                 CALL CLOSE(3)
                 OUT=.FALSE.
                 IF(VT100)CALL ERLINE
         C
         C       GET NEW OUTPUT FILE SPECIFICATION AND WRITE DATA INTO IT
         C
         970     CALL OUTPT
                 RETURN
         2080    FORMAT(A2)
         2420    FORMAT(1H$,16X,'FILE ',7A2,' ALREADY OPEN.  NEW FILE NEEDED? ')
                 END
```

```
FORTRAN IV-PLUS V02-51             09:18:28     04-SEP-80           PAGE 2
OMEG5F.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME         SIZE                       ATTRIBUTES

   1      $CODE1    000256     87                 RW,I,CON,LCL
   2      $PDATA    000004      2                 RW,D,CON,LCL
   3      $IDATA    000074     30                 RW,D,CON,LCL
   4      $VARS     000004      2                 RW,D,CON,LCL
   6      .$$$$.    000002      1                 RW,D,OVR,GBL
   7      NPC       000010      4                 RW,D,OVR,GBL
   8      OUTFIL    000022      9                 RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS

 OUTP           1-000000

VARIABLES

 NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS     NAME    TYPE   ADDRESS

 I       I*2    4-000000    IC      I*2    4-000002    NOPAC   I*2    7-000000    NOPAC1  I*2    7-000002    NOPAC2  I*2    7-000004
 OUT     L*1    7-000006    VT100   L*1    6-000000

ARRAYS

 NAME    TYPE   ADDRESS          SIZE          DIMENSIONS

 IOFILE  I*2    8-000000    000022      9      (9)

LABELS

 LABEL    ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 970      1-000236          2080'   3-000000          2420'   3-000004

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE    ERLINE   OUTPT

TOTAL SPACE ALLOCATED = 000416    135

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51        09:18:30    04-SEP-80          PAGE 3
OMEG5F.FTN        /TR:BLOCKS/WR

0001                    SUBROUTINE BEGIN
              C
              C         INITIALIZE A NEW REPORT INTERVAL
              C
0002                    BYTE VT100,OUT
0003                    COMMON VT100
0004                    COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
0005                    IF(VT100)CALL ERLINE
              C
              C         IS REPORT INTERVAL OPEN?
              C
0006                    IF(NOPAC.EQ.0)GOTO 1000
              C
              C         YES, TELL OPERATOR AND VERIFY NEED FOR NEW ONE
              C
0007                    WRITE(5,2440)
0008                    READ(5,2080)IC
0009                    IF(IC.NE.'Y '.AND.IC.NE.'YE')RETURN      !IF NO, GET NEW COMMAND
              C
              C         INITIALIZE REPORT ARRAYS
              C
0010          1000      NOPAC=0
0011                    NOPAC2=0
0012                    NOPAC1=1
0013                    CALL CLOSE(3)     !CLOSE THE CURRENTLY OPEN OUTPUT FILE
0014                    OUT=.FALSE.
0015                    IF(VT100)CALL ERLINE
              C
              C         GET NEW OUTPUT FILE SPECIFICATION AND WRITE DATA INTO IT.
              C
0016                    CALL OUTPT
0017                    RETURN
0018          2080      FORMAT(A2)
0019          2440      FORMAT(1H$,16X,'REPORT INTERVAL ALREADY OPEN.'
                        1,   'NEW INTERVAL NEEDED? ')
0020                    END
```

```
FORTRAN IV-PLUS V02-51            09:18:30    04-SEP-80         PAGE 4
OMEG5F.FTN         /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE               ATTRIBUTES

  1     $CODE1   000230    76           RW,I,CON,LCL
  2     $PDATA   000004     2           RW,D,CON,LCL
  3     $IDATA   000106    35           RW,D,CON,LCL
  4     $VARS    000002     1           RW,D,CON,LCL
  6     .$$$$.   000002     1           RW,D,OVR,GBL
  7     NPC      000010     4           RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 BEGIN         1-000000

VARIABLES

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 IC     I*2   4-000000     NOPAC  I*2   7-000000    NOPAC1 I*2   7-000002    NOPAC2 I*2   7-000004    OUT    L*1   7-000006
 VT100  L*1   6-000000

LABELS

 LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 1000    1-000140         2080'   3-000000         2440'   3-000004

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   ERLINE   OUTPT

TOTAL SPACE ALLOCATED = 000356   119

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51          09:18:31    04-SEP-80           PAGE 5
OMEG5F.FTN        /TR:BLOCKS/WR

0001                SUBROUTINE EN
          C
          C         END REPORT INTERVAL AND WRITE INFORMATION ON THE OUTPUT FILE.
          C
0002                BYTE VT100,OUT
0003                COMMON VT100
0004                COMMON /REPORT/REP(14,136),IREP(12,136)
0005                COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
0006                COMMON /ACC1/ITCNT,STIM,SAVEC,NSIG,NAVE,OSIGSM,OPSUM
0007                IF(VT100)CALL ERLINE
          C
          C         IF AN OUTPUT FILE IS NOT OPEN, ASK FOR OUTPUT FILE SPECIFICATION
          C         AND WRITE DATA IN REPORT ARRAYS INTO IT IF ONE IS PROVIDED.
          C
0008                IF(.NOT.OUT)CALL OUTPT
0009                CALL CLOSE(3)    !CLOSE THE CURRENTLY OPEN OUTPUT FILE
0010                OUT=.FALSE.
0011                IF(NOPAC.GT.IREP(12,NOPAC))GOTO 1050
          C
          C         ALL DATA IN THE REPORT ARRAYS IS NEEDED FOR THE CURRENT RUNNING AVERAGE
          C
0012                NOPAC1=NOPAC+1
0013                NOPAC2=NOPAC
0014                GOTO 1058
          C
          C         SAVE ONLY THE DATA IN THE REPORT ARRAYS NEEDED FOR THE CURRENT
          C         RUNNING AVERAGE
          C
0015      1050      NOPAC1=NOPAC-ITCNT+2
0016                N=ITCNT-1
0017                NOPAC=NOPAC1-1
0018                NOPAC2=0
0019                ITCNT=1
          C
          C         MOVE DATA FOR CURRENT RUNNING AVERAGE FROM END OF REPORT ARRAYS TO
          C         BEGINNING.
          C
0020                DO 1056 I=1,NOPAC
0021                 DO 1054 II=1,12
0022                  IREP(II,I)=IREP(II,I+N)
0023                  REP(II,I)=REP(II,I+N)
0024      1054       CONTINUE
0025                 REP(13,I)=REP(13,I+N)
0026                 REP(14,I)=REP(14,I+N)
0027      1056      CONTINUE
          C
          C         GET NEW OUTPUT FILE SPECIFICATION AND WRITE DATA FROM REPORT ARRAYS
          C         INTO IT
          C
0028      1058      CALL OUTPT
0029                RETURN
0030                END
```

```
FORTRAN IV-PLUS V02-51          09:18:31    04-SEP-80         PAGE 6
OMEG5F.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                   ATTRIBUTES

  1     $CODE1   000474    158             RW,I,CON,LCL
  2     $PDATA   000004      2             RW,D,CON,LCL
  3     $IDATA   000006      3             RW,D,CON,LCL
  4     $VARS    000006      3             RW,D,CON,LCL
  5     $TEMPS   000006      3             RW,D,CON,LCL
  6     .$$$$.   000002      1             RW,D,OVR,GBL
  7     REPORT   025200   5440             RW,D,OVR,GBL
  8     NPC      000010      4             RW,D,OVR,GBL
  9     ACC1     000026     11             RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS

 EN            1-000000

VARIABLES

 NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS    NAME    TYPE  ADDRESS

 I       I*2   4-000002   II      I*2   4-000004   ITCNT   I*2   9-000000   N       I*2   4-000000   NAVE    I*2   9-000014
 NOPAC   I*2   8-000000   NOPAC1  I*2   8-000002   NOPAC2  I*2   8-000004   NSIG    I*2   9-000012   OPSUM   R*4   9-000022
 OSIGSM  R*4   9-000016   OUT     L*1   8-000006   SAVEC   R*4   9-000006   STIM    R*4   9-000002   VT100   L*1   6-000000

ARRAYS

 NAME    TYPE  ADDRESS        SIZE          DIMENSIONS

 IREP    I*2   7-016700  006300  1632      (12,136)
 REP     R*4   7-000000  016700  3808      (14,136)

LABELS

 LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS

 1050     1-000132        1054       **            1056       **            1058     1-000454

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE    ERLINE   OUTPT

TOTAL SPACE ALLOCATED = 025762   5625
```

```
FORTRAN IV-PLUS V02-51         09:18:34     04-SEP-80            PAGE 7
OMEG5F.FTN        /TR:BLOCKS/WR

                  SUBROUTINE OUTPT
             C
             C    THIS SUBROUTINE WRITES OUTPUT DATA TO THE FILE CONNECTED
             C    TO UNIT 3
             C    IF THERE IS NO FILE OPEN, A FILE SPECIFICATION IS REQUESTED
             C    AND IF ONE IS PROVIDED, THE FILE IS OPENED AND THE DATA FROM THE
             C    REPORT ARRAYS IS WRITTEN INTO IT
             C
             C
                  BYTE OUT,VT100
                  COMMON VT100
                  COMMON /REPORT/REP(14,136),IREP(12,136)
                  COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
                  COMMON /AUXIL/IAUX(52,3)
                  COMMON /OUTFIL/IOFILE(9)
                  IF(OUT)GOTO 200
          110     IF(VT100)CALL ERLINE
                  WRITE(5,1200)
                  READ(5,1400)IOFILE
                  IF(IOFILE(2).EQ.'  ')RETURN
                  IOFILE(9)=0
                  CALL CLOSE(3)
                  OPEN(UNIT=3,NAME=IOFILE,ERR=120,DISPOSE='SAVE')
                  GOTO 130
          120     IF(VT100)CALL ERLINE
                  WRITE(5,1300)
                  CALL WAIT(3,2,IWSTAT)
                  GOTO 110
          130     OUT=.TRUE.
          200     WRITE(3,1000)(IAUX(I,1),I=1,52)
                  IF(NOPAC.EQ.0)RETURN
                  DO 10 I=1,NOPAC
                  WRITE(3,1100)(IREP(J,I),J=1,12),(REP(J,I),J=1,14)
          10      CONTINUE
                  RETURN
          1000    FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
          1100    FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
          1200    FORMAT(1H$,16X,'ENTER OUTPUT FILE SPECIFICATION: ')
          1300    FORMAT(17X,'ERROR OPENING DISC FILE!')
          1400    FORMAT(20A2)
                  END
```

```
FORTRAN IV-PLUS V02-51              09:18:34     04-SEP-80          PAGE 8
OMEG5F.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                      ATTRIBUTES

  1      $CODE1   000602    193                RW,I,CON,LCL
  2      $PDATA   000010      4                RW,D,CON,LCL
  3      $IDATA   000242     81                RW,D,CON,LCL
  4      $VARS    000006      3                RW,D,CON,LCL
  6      .$$$$.   000002      1                RW,D,CON,LCL
  7      REPORT   025200   5440                RW,D,OVR,GBL
  8      NPC      000010      4                RW,D,OVR,GBL
  9      AUXIL    000470    156                RW,D,OVR,GBL
 10      OUTFIL   000022      9                RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 OUTPT        1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 I      I*2   4-000002   IWSTAT I*2   4-000000   J      I*2   4-000004   NOPAC  I*2   8-000000   NOPAC1 I*2   8-000002
 NOPAC2 I*2   8-000004   OUT    L*1   8-000006   VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS       SIZE          DIMENSIONS

 IAUX   I*2    9-000000  000470   156     (52,3)
 IOFILE I*2   10-000000  000022     9     (9)
 IREP   I*2    7-016700  006300  1632     (12,136)
 REP    R*4    7-000000  016700  3808     (14,136)

LABELS

 LABEL  ADDRESS     LABEL  ADDRESS     LABEL  ADDRESS     LABEL  ADDRESS     LABEL  ADDRESS

 10        **       110    1-000030    120    1-000174    130    1-000262    200    1-000276
 1000'  3-000000    1100'  3-000036    1200'  3-000060    1300'  3-000130    1400'  3-000166

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   ERLINE  OPEN$   WAIT

TOTAL SPACE ALLOCATED = 027006   5891

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51          09:18:34    04-SEP-80           PAGE 9
OMEG5F.FTN       /TR:BLOCKS/WR

SYO:[101,1]OMEG5F,SYO:[101,1]OMEG5F/-SP=SYO:[101,1]OMEG5F
```

```
FORTRAN IV-PLUS V02-51E         09:10:07    02-DEC-80           PAGE 1
OMEGSG.FTN        /TR:BLOCKS/WR

0001                 SUBROUTINE ACC
           C
           C         ACCEPT OR REJECT LAST CALCULATED VALUE
           C
0002                 BYTE VT100,OUT,REF,NEWO,AVE
0003                 COMMON VT100
0004                 COMMON /AUXIL/IAUX(52,3)
0005                 COMMON /REPORT/REP(14,136),IREP(12,136)
0006                 COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
0007                 COMMON /ACC1/ITCNT,STIM,SAVEC,NSIG,NAVE,OSIGSM,OPSUM
0008                 COMMON /AVGE/SAVE,AVE
0009                 COMMON /ACC2/REF,NEWO,RN,RSIGN,RF,RSIGF,DN,DSIGN,DF,DSIGF,
                     1OP,OPSIG,OPC
0010                 COMMON /PICK2/INC,KNEAR,KFAR
0011                 IF(VT100)CALL ERLINE
           C
           C         IF NEW OPACITY IS NOT AVAILABLE, GET NEW COMMAND
           C
0012                 IF(.NOT.NEWO)RETURN
0013                 IF(NOPAC.LT.136)GOTO 1075
0014                 WRITE(5,2770)     !REPORT ARRAYS ARE FULL, TELL OPERATOR
0015                 RETURN
0016       1075      NOPAC=NOPAC+1
0017                 NOPAC2=NOPAC2+1
0018                 I=NOPAC
0019                 IF(I.GT.1)GOTO 1080
           C
           C         THIS IS THE FIRST VALUE IN THE REPORT.  INITIALIZE ACCUMULATORS AND
           C         TIME FOR THE RUNNING AVERAGE.
           C
0020                 NAVE=0
0021                 SAVEC=0.0
0022                 NSIG=0
0023                 OPSUM=0.0
0024                 OSIGSM=0.0
0025                 STIM=IAUX(4,1)*60.0+IAUX(5,1)+IAUX(6,1)/60.0
0026                 ITCNT=I
0027       1080      IF(AVE)GOTO 1090
           C
           C         A RUNNING AVERAGE IS NOT BEING CALCULATED
           C
0028                 STIM=0.0
0029                 ITCNT=0
           C
           C         COPY DATE, TIME AND FILE NUMBER FROM THE AUXILIARY ARRAY TO IREP
           C
0030       1090      DO 1100 L=1,7
0031                  IREP(L,I)=IAUX(L,1)
0032       1100      CONTINUE
0033                 IREP(8,I)=IAUX(7,2)       !REFERENCE FILE NUMBER
0034                 IF(.NOT.REF)IREP(8,I)=0 !NO REFERENCE USED
0035                 IREP(9,I)=(KNEAR-1)*INC  !NEAR PICK POINT
0036                 IREP(10,I)=(KFAR-1)*INC  !FAR PICK POINT
0037                 REP(1,I)=DN
           C
           C         DATA AND REFERENCE VALUES AT BOTH PICK POINTS
```

```
      C
0038              REP(2,I)=DSIGN
0039              REP(3,I)=0.0
0040              REP(4,I)=0.0
0041              IF(REF)REP(3,I)=RN
0042              IF(REF)REP(4,I)=RSIGN
0043              REP(5,I)=DF
0044              REP(6,I)=DSIGF
0045              REP(7,I)=0.0
0046              REP(8,I)=0.0
0047              IF(REF)REP(7,I)=RF
0048              IF(REF)REP(8,I)=RSIGF
      C
      C           OPACITY AND SO
      C
0049              REP(9,I)=OP
0050              REP(10,I)=OPC
0051              REP(11,I)=OPSIG
0052              IREP(11,I)=0
0053              IREP(12,I)=0
0054              REP(12,I)=0.0
0055              REP(13,I)=0.0
0056              REP(14,I)=0.0
0057              NEWO=.FALSE.
      C
      C           TELL OPERATOR WHICH SHOT HAS BEEN ACCEPTED AND HOW MANY THERE ARE SO FAR
      C
0058              WRITE(5,2780)IAUX(7,1),NOPAC2,NOPAC
0059              IF(.NOT.AVE)GOTO 1115
      C
      C           CALCULATE THE NEW RUNNING AVERAGE
      C
0060              TIME=IAUX(4,1)*60.0+IAUX(5,1)+IAUX(6,1)/60.0
      C
      C           MIDNIGHT CORRECTION
      C
0061              IF(TIME.LT.STIM)TIME=TIME+1440.0
0062      1110    IF(STIM+SAVE.LT.TIME)GOTO 1120
      C
      C           ADD THE CURRENT VALUE OF SO TO THE RUNNING AVERAGE
      C
0063              NSIG=NSIG+1
0064              OSIGSM=OSIGSM+OPSIG
0065              REP(13,I)=OSIGSM/NSIG
0066              IREP(12,I)=NSIG
0067              SAVEC=TIME-STIM
0068              REP(14,I)=SAVEC
0069              IREP(11,I)=NAVE
0070              IF(NAVE.GT.0)REP(12,I)=OPSUM/NAVE
      C
      C           ADD THE CURRENT VALUE OF OPACITY TO THE RUNNING AVERAGE IF SO IS
      C           8 OR LESS (FIGURED TO THE NEAREST INTEGER
      C
0071              IF(OPSIG.GE.8.5)GOTO 1115
0072              NAVE=NAVE+1
0073              OPSUM=OPSUM+OPC
```

```
FORTRAN IV-PLUS V02-51E        09:10:07    02-DEC-80          PAGE 3
OMEG5G.FTN          /TR:BLOCKS/WR

0074                IREP(11,I)=NAVE
0075                REP(12,I)=OPSUM/NAVE
          C
          C         IF AN OUTPUT FILE IS OPEN, WRITE THE INFORMATION FROM THIS SHOT
          C         INTO IT
          C
0076      1115      IF(OUT)WRITE(3,2760)(IREP(L,I),L=1,12),(REP(L,I),L=1,14)
0077                RETURN
          C
          C         VALUES NEED TO BE SUBTRACTED FROM THE BEGINNING OF THE RUNNING AVERAGE
          C
0078      1120      NSIG=NSIG-1
          C
          C         SUBTRACT FIRST SO FROM THE RUNNING AVERAGE
          C
0079                OSIGSM=OSIGSM-REP(11,ITCNT)
0080                ITCNT=ITCNT+1
0081                STIM=IREP(4,ITCNT)*60.0+IREP(5,ITCNT)+IREP(6,ITCNT)/60.0
0082                IF(STIM+1440.0.LE.TIME)TIME=TIME-1440.0
0083                IF(REP(11,ITCNT-1).GE.8.5)GOTO 1110
          C
          C         IF THE VALUE OF SO JUST SUBTRACTED WAS 8 OR LESS, SUBTRACT THE
          C         CORRESPONDING VALUE OF OPACITY FROM THE RUNNING AVERAGE
          C
0084                NAVE=NAVE-1
0085                OPSUM=OPSUM-REP(10,ITCNT-1)
0086                GOTO 1110
0087      2760      FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
0088      2770      FORMAT(17X,'REPORT FILES FULL.   DATA NOT ACCEPTED!!!')
0089      2780      FORMAT(17X,'SHOT',I5,' RECORDED.',I5,
                    1' VALUES ARE IN THE REPORT.',I5,' SHOTS IN THE FILE.')
0090                END
```

```
FORTRAN IV-PLUS V02-51E          09:10:07    02-DEC-80          PAGE 4
OMEGSQ.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

  1      $CODE1    001666   475            RW,I,CON,LCL
  3      $IDATA    000216    71            RW,D,CON,LCL
  4      $VARS     000010     4            RW,D,CON,LCL
  6      .$$$$.    000002     1            RW,D,OVR,GBL
  7      AUXIL     000470   156            RW,D,OVR,GBL
  8      REPORT    025200  5440            RW,D,OVR,GBL
  9      NPC       000010     4            RW,D,OVR,GBL
 10      ACC1      000026    11            RW,D,OVR,GBL
 11      AVGE      000006     3            RW,D,OVR,GBL
 12      ACC2      000056    23            RW,D,OVR,GBL
 13      PICK2     000006     3            RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS

 ACC             1-000000

VARIABLES

 NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS      NAME    TYPE   ADDRESS

 AVE     L*1   11-000004     DF      R*4   [illegible]000032     DN      R*4   12-000022     DSIGF   R*4   12-000036     DSIGN   R*4   12-000026
 I       I*2    4-000000     INC     I*2   1[illegible]000000     ITCNT   I*2   10-000000     KFAR    I*2   13-000004     KNEAR   I*2   13-000002
 L       I*2    4-000002     NAVE    I*2   10-000014     NEWO    L*1   12-000001     NOPAC   I*2    9-000000     NOPAC1  I*2    9-000002
 NOPAC2  I*2    9-000004     NSIG    I*2   10-000012     OP      R*4   12-000042     OPC     R*4   12-000052     OPSIG   R*4   12-000046
 OPSUM   R*4   10-000022     OSIGSM  R*4   10-000016     OUT     L*1    9-000006     REF     L*1   12-000000     RF      R*4   12-000012
 RN      R*4   12-000002     RSIGF   R*4   12-000016     RSIGN   R*4   12-000006     SAVE    R*4   11-000000     SAVEC   R*4   10-000006
 STIM    R*4   10-000002     TIME    R*4    4-000004     VT100   L*1    6-000000

ARRAYS

 NAME    TYPE   ADDRESS          SIZE           DIMENSIONS

 IAUX    I*2    7-000000   000470    156        (52,3)
 IREP    I*2    8-016700   006300   1632        (12,136)
 REP     R*4    8-000000   016700   3808        (14,136)

LABELS

 LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 1075    1-000100         1080    1-000226         1090    1-000254         1100       **            1110    1-001030
 1115    1-001264         1120    1-001450         2760'   3-000000         2770'   3-000022         2780'   3-000100

FUNCTIONS AND SUBROUTINES REFERENCED
```

```
FORTRAN IV-PLUS V02-51E          09:10:07    02-DEC-80           PAGE 5
OMEG5O.FTN       /TR:BLOCKS/WR

 ERLINE

TOTAL SPACE ALLOCATED = 030136  6191
```

```
FORTRAN IV-PLUS V02-51E        09:10:13     02-DEC-80          PAGE 6
OMEG5G.FTN        /TR:BLOCKS/WR

0001                SUBROUTINE AUT
0002                BYTE AUTO,VT100,RESID,PLUME
0003                COMMON VT100
0004                COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
0005                AUTO=.NOT.AUTO
0006                IF(VT100)CALL ERLINE
0007                IF(AUTO)WRITE(5,1000)
0008                IF(.NOT.AUTO)WRITE(5,1010)
0009                CALL WAIT(1,2,IWSTAT)
0010                RETURN
0011      1000      FORMAT(17X,'PICK POINTS WILL BE SELECTED AUTOMATICALLY.')
0012      1010      FORMAT(17X,'PICK POINTS WILL BE SELECTED MANUALLY.')
0013                END
```

```
FORTRAN IV-PLUS V02-51E           09:10:13     02-DEC-80           PAGE 7
OMEG5G.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME        SIZE                 ATTRIBUTES

   1     $CODE1   000130     44            RW,I,CON,LCL
   2     $PDATA   000010      4            RW,D,CON,LCL
   3     $IDATA   000146     51            RW,D,CON,LCL
   4     $VARS    000002      1            RW,D,CON,LCL
   6     .$$$$.   000002      1            RW,D,OVR,GBL
   7     PICKS    000010      4            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AUT          1-000000

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AUTO   L*1   7-000004   IFAR   I*2   7-000002   IWSTAT I*2   4-000000   NEAR   I*2   7-000000   PLUME  L*1   7-000006
 RESID  L*1   7-000005   VT100  L*1   6-000000

LABELS

 LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS

 1000'  3-000000         1010'  3-000060

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  WAIT

TOTAL SPACE ALLOCATED = 000322   105

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        09:10:14    02-DEC-80           PAGE 8
OMEG5G.FTN      /TR:BLOCKS/WR

                SUBROUTINE SET
        C
        C       SET THE LIMITS FOR THE AUTOMATIC PICK POINT SEARCH.
        C
                BYTE VT100
                COMMON VT100
                COMMON /LIMITS/LIMLO,LIMHI
                COMMON /STACK/NPLUM,NSTK,ELSTK,AZSTK
                COMMON /AUXIL/IAUX(52,3)
                INC=10
                IF(IAUX(11,1).GE.10)INC=IAUX(11,1)
                IF(VT100)CALL ERLINE
                WRITE(5,1000)
                IF(VT100)CALL WAIT(1,2,IWSTAT)
                LIML=(LIMLO-1)*INC
                IF(VT100)CALL ERLINE
                WRITE(5,1010)LIML
                CALL RDCHK(LIML)
                LIMLO=LIML/INC+1
                LIMH=(LIMHI-1)*INC
                IF(VT100)CALL ERLINE
                WRITE(5,1020)LIMH
                CALL RDCHK(LIMH)
                LIMHI=LIMH/INC+1
                IF(NPLUM.GE.LIMH.OR.NPLUM.LE.LIML)NPLUM=LIMH-200
                RETURN
        1000    FORMAT(17X,'ENTER UPPER AND LOWER LIMITS FOR PICK POINT SEARCH')
        1010    FORMAT(1H$,16X,'LOWER LIMIT IS',I6,' NS.  CHANGE TO: ')
        1020    FORMAT(1H$,16X,'UPPER LIMIT IS',I6,' NS.  CHANGE TO: ')
                END
```

```
FORTRAN IV-PLUS V02-51E          09:10:14    02-DEC-80           PAGE 9
OMEG5G.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME       SIZE                  ATTRIBUTES

  1      $CODE1   000406   131             RW,I,CON,LCL
  2      $PDATA   000010     4             RW,D,CON,LCL
  3      $IDATA   000236    79             RW,D,CON,LCL
  4      $VARS    000010     4             RW,D,CON,LCL
  6      .$$$$.   000002     1             RW,D,OVR,GBL
  7      LIMITS   000004     2             RW,D,OVR,GBL
  8      STACK    000014     6             RW,D,OVR,GBL
  9      AUXIL    000470   156             RW,D,OVR,GBL


ENTRY POINTS

 NAME    TYPE   ADDRESS     NAME.  TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS

 SET            1-000000


VARIABLES

 NAME    TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS     NAME   TYPE   ADDRESS

 AZSTK   R*4    8-000010    ELSTK  R*4    8-000004    INC    I*2    4-000000    IWSTAT I*2    4-000002    LIMH   I*2    4-000006
 LIMHI   I*2    7-000002    LIML   I*2    4-000004    LIMLO  I*2    7-000000    NPLUM  I*2    8-000000    NSTK   I*2    8-000002
 VT100   L*1    6-000000


ARRAYS

 NAME    TYPE   ADDRESS       SIZE         DIMENSIONS

 IAUX    I*2    9-000000   000470   156    (52,3)


LABELS

 LABEL   ADDRESS            LABEL  ADDRESS            LABEL  ADDRESS            LABEL  ADDRESS            LABEL  ADDRESS

 1000'   3-000000           1010'  3-000070           1020'  3-000142


FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE  RDCHK   WAIT


TOTAL SPACE ALLOCATED = 001376   383

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E         09:10:16    02-DEC-80          PAGE 10
OMEG5G.FTN         /TR:BLOCKS/WR

                    SUBROUTINE RES
                    BYTE VT100,RESID,AUTO,PLUME
                    COMMON VT100
                    COMMON /PICKS/NEAR,IFAR,AUTO,RESID,PLUME
                    RESID=.NOT.RESID
                    IF(VT100)CALL ERLINE
                    IF(RESID)WRITE(5,1000)
                    IF(.NOT.RESID)WRITE(5,1010)
                    RETURN
          1000      FORMAT(17X,'RESIDUAL PLUME OPACITY CORRECTION WILL BE MADE.')
          1010      FORMAT(17X,'NO RESIDUAL PLUME OPACITY CORRECTION WILL BE MADE.')
                    END
```

```
FORTRAN IV-PLUS V02-51E          09:10:16    02-DEC-80          PAGE 11
OMEG5G.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME          SIZE                 ATTRIBUTES

  1      $CODE1   000120     40             RW,I,CON,LCL
  3      $IDATA   000156     55             RW,D,CON,LCL
  6      .$$$$.   000002      1             RW,D,OVR,GBL
  7      PICKS    000010      4             RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 RES           1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 AUTO    L*1   7-000004    IFAR    I*2   7-000002    NEAR    I*2   7-000000    PLUME   L*1   7-000006    RESID   L*1   7-000005
 VT100   L*1   6-000000

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 1000'   3-000000          1010'   3-000064

FUNCTIONS AND SUBROUTINES REFERENCED

 ERLINE

TOTAL SPACE ALLOCATED = 000310   100

NO FPP INSTRUCTIONS GENERATED
```

```
FORTRAN IV-PLUS V02-51E        09:10:17    02-DEC-80          PAGE 12
OMEG5G.FTN       /TR:BLOCKS/WR

0001                 SUBROUTINE HELP
              C
              C      THIS SUBROUTINE DISPLAYS A LIST OF THE AVAILABLE COMMANDS ON THE
              C      TERMINAL.  OPTIONALLY, A COMPLETE DESCRIPTION OF THE COMMANDS CAN BE
              C      PRINTED, OR INFORMATION ABOUT A SINGLE COMMAND CAN BE DISPLAYED ON THE
              C      TERMINAL.
              C
0002                 BYTE VT100
0003                 COMMON VT100
0004                 COMMON /COMMAN/ICOM(51)
0005                 WRITE(5,1000)"33,"143
0006                 VT100=.FALSE.
0007                 CALL WAIT(3,2,IWSTAT)
0008                 WRITE(5,1010)
0009                 WRITE(5,1020)
0010                 WRITE(5,1030)
0011          5      READ(5,1040,END=390)IC
0012                 IU=5
0013                 IF(IC.EQ.'  ')RETURN
0014                 IF(IC.EQ.'AL')GOTO 30
0015                 DO 10 I=1,49
0016                 IF(IC.EQ.ICOM(I))GOTO 20
0017          10     CONTINUE
0018          20     GOTO(330,330,340,290,300,100,100,290,310,210,210,160,160,170,190
                     1,200,200,220,380,380,370,90,90,360,110,120,260,180,180,280,240
                     2,240,250,80,80,140,140,60,40,40,270,270,230,150,50,350,320,130
                     3,70)I
0019                 WRITE(5,1050)IC
0020                 GOTO 5
0021          30     IU=6
0022                 WRITE(6,1060)
0023          40     WRITE(IU,1070)          !:A :AC
0024                 IF(IU.EQ.5)RETURN
0025          50     WRITE(IU,1080)          !:AU
0026                 IF(IU.EQ.5)RETURN
0027          60     WRITE(IU,1090)          !:AV
0028                 IF(IU.EQ.5)RETURN
0029          70     WRITE(IU,1100)          !:BA
0030                 IF(IU.EQ.5)RETURN
0031          80     WRITE(IU,1110)          !:B :BE
0032                 IF(IU.EQ.5)RETURN
0033          90     WRITE(IU,1120)          !:C :CO
0034                 IF(IU.EQ.5)RETURN
0035          100    WRITE(IU,1130)          !:D :DA
0036                 IF(IU.EQ.5)RETURN
0037          110    WRITE(IU,1140)          !:DI
0038                 IF(IU.EQ.5)RETURN
0039          120    WRITE(IU,1150)          !:DX
0040                 IF(IU.EQ.5)RETURN
0041          130    WRITE(IU,1160)          !:DY
0042                 IF(IU.EQ.5)RETURN
0043          140    WRITE(IU,1170)          !:E :EN
0044                 IF(IU.EQ.5)RETURN
0045          150    WRITE(IU,1180)          !:EX
0046                 IF(IU.EQ.5)RETURN
0047          160    WRITE(IU,1190)          !:F :FA
```

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FORTRAN IV-PLUS V02-51E         09:10:17    02-DEC-80           PAGE 13
OMEGSG.FTN          /TR:BLOCKS/WR

                    IF(IU.EQ.5)RETURN
          170       WRITE(IU,1200)            !:FI
                    IF(IU.EQ.5)RETURN
          180       WRITE(IU,1210)            !:H :HE
                    IF(IU.EQ.5)RETURN
          190       WRITE(IU,1220)            !:ID
                    IF(IU.EQ.5)RETURN
          200       WRITE(IU,1230)            !:L :LI
                    IF(IU.EQ.5)RETURN
          210       WRITE(IU,1240)            !:N :NE
                    IF(IU.EQ.5)RETURN
          220       WRITE(IU,1250)            !:NO
                    IF(IU.EQ.5)RETURN
          230       WRITE(IU,1260)            !:OF
                    IF(IU.EQ.5)RETURN
          240       WRITE(IU,1270)            !:O :OP
                    IF(IU.EQ.5)RETURN
          250       WRITE(IU,1280)            !:OU
                    IF(IU.EQ.5)RETURN
          260       WRITE(IU,1290)            !:PK
                    IF(IU.EQ.5)RETURN
          270       WRITE(IU,1300)            !:P :PR
                    IF(IU.EQ.5)RETURN
          280       WRITE(IU,1310)            !:RC
                    IF(IU.EQ.5)RETURN
          290       WRITE(IU,1320)            !:R :RD
                    IF(IU.EQ.5)RETURN
          300       WRITE(IU,1330)            !:RE
                    IF(IU.EQ.5)RETURN
          310       WRITE(IU,1340)            !:RR
                    IF(IU.EQ.5)RETURN
          320       WRITE(IU,1350)            !:RS
                    IF(IU.EQ.5)RETURN
          330       WRITE(IU,1360)            !:S :SO
                    IF(IU.EQ.5)RETURN
          340       WRITE(IU,1370)            !:ST
                    IF(IU.EQ.5)RETURN
          350       WRITE(IU,1380)            !:SL
                    IF(IU.EQ.5)RETURN
          360       WRITE(IU,1390)            !:TO
                    IF(IU.EQ.5)RETURN
          370       WRITE(IU,1400)            !:T2
                    IF(IU.EQ.5)RETURN
          380       WRITE(IU,1410)            !:Y :YE
                    IF(IU.EQ.6)CALL CLOSE(6)
          390       RETURN
          C
          C         FORMAT STATEMENTS
          C
          1000      FORMAT(1H+,2A1)
          1010      FORMAT(' THE FOLLOWING COMMANDS ARE AVAILABLE:'/)
          1020      FORMAT(' A AC  ACCEPT',T22,'AU    AUTO FLAG',T42,'AV    AVERAGE'
                    2,T62,'BA    BACK'/
                    1' B BE  BEGIN',T22,'C CO  COMP FLAG',T42,'D DA  DATA'
                    2,T62,'DI    DISPLAY'/
                    1' DX    DISPLAY-X',T22,'DY    DISPLAY-Y',T42,'E EN  END'
```

```
                        2,T62,'EX     EXIT'/
                        1' F FA  FAR PICK',6X,'FI     FILE NUMBER    H HE   HELP'
                        2,T62,'ID     ID HEADER'/
                        1' L LI  LIST SHOT      N NE   NEAR PICK      NO     NO REF'
                        2,T62,'OF     OLD FILE'/
                        1' O OP  OPACITY',7X,'OU     OUTPUT FILE'
                        2,T42,'PK     PICK POINTS    P PR   PRINT REPORT'/
                        1' RC     RN,RF CALC     R RD   READ DATA'
                        2,T42,'RE     REF SHOT',T62,'RR     READ REF SHOT'/
                        1' RS     RESID FLAG     S SO   SOURCE'
                        2,T42,'ST     START OVER     SL     SEARCH LIMITS'/
                        1' TO     TIME REF',6X,'T2     T2 FLAG',7X,'Y YE   YES REF'/)
0097      1030          FORMAT(' FOR MORE INFORMATION, TYPE THE COMMAND.'/' FOR A COMP',
                        1'LETE DESCRIPTION OF THE COMMANDS ON THE PRINTER, TYPE "ALL".')
0098      1040          FORMAT(A2)
0099      1050          FORMAT(1X,A2,' IS NOT A VALID COMMAND.  TRY AGAIN.')
0100      1060          FORMAT(' OMEGA-1 LIDAR.   OPACITY DATA ANALYSIS PROGRAM.',3X,
                        1'DESCRIPTION OF COMMANDS.'/)
0101      1070          FORMAT('O:A :AC  ACCEPT;  STORE THE LATEST CALCULATED OPACITY '
                        1,'IN THE REPORT ARRAYS,'/9X,'AND ADD THE INFORMATION TO THE '
                        2,'OUTPUT FILE IF ONE IS OPEN.')
0102      1080          FORMAT('O:AU      AUTO FLAG;  CHANGES THE STATE OF THE AUTO '
                        1,'FLAG.  PICK POINTS ARE'/9X,'SELECTED AUTOMATICALLY OR '
                        2,'MANUALLY DEPENDING ON THE STATE OF THE FLAG.')
0103      1090          FORMAT('O:AV      AVERAGE;  SPECIFY THE AVERAGING INTERVAL IN '
                        1,'MINUTES.')
0104      1100          FORMAT('O:BA      BACK TO PLUME;  RESTART THE PICK POINT SEARCH '
                        1,'AT THE PLUME.')
0105      1110          FORMAT('O:B :BE  BEGIN REPORT INTERVAL;  INITIALIZE REPORT '
                        1,'COUNTERS.  IF AN OUTPUT FILE'/9X,'IS NOT OPEN, ONE MAY BE '
                        2,'OPENED TO SAVE THE REPORT ARRAYS BEFORE THEY ARE'/9X,'LOST.'
                        3,'  A NEW OUTPUT FILE MAY THEN BE SPECIFIED FOR FUTURE DATA.')
0106      1120          FORMAT('O:C :CO  COMP FLAG;  CHANGES THE STATE OF THE COMP '
                        1,'FLAG.  DATA IS COMPENSATED'/9X,'OR NOT DEPENDING ON THE '
                        2,'STATE OF THE FLAG.')
0107      1130          FORMAT('O:D :DA  DATA;  DATA SHOT WILL BE USED FOR DISPLAY, ID,'
                        1,' AND LIST.')
0108      1140          FORMAT('O:DI      DISPLAY;  DISPLAY ON THE VT100 SCREEN THE '
                        1,'REFERENCE SHOT OR DATA SHOT,'/9X,'WHICHEVER IS SELECTED.')
0109      1150          FORMAT('O:DX      DISPLAY-X;  SELECT THE X-RESOLUTION FOR THE '
                        1,'DISPLAY.')
0110      1160          FORMAT('O:DY      DISPLAY-Y;  SELECT THE Y-RESOLUTION FOR THE '
                        1,'DISPLAY.')
0111      1170          FORMAT('O:E :EN  END REPORT INTERVAL;  THE OUTPUT FILE IS '
                        1,'CLOSED.  IF A FILE IS NOT OPEN,'/9X,'ONE MAY OPENED TO '
                        2,'SAVE THE REPORT ARRAYS BEFORE THEY ARE MODIFIED.'/9X,'THE '
                        3,'REPORT ARRAYS ARE THEN PURGED SO THAT ONLY THE VALUES '
                        4,'NEEDED FOR'/9X,'THE LAST RUNNING AVERAGE ARE INCLUDED.  A '
                        5,'NEW OUTPUT FILE MAY THEN BE'/9X,'SPECIFIED TO SAVE THE '
                        6,'UPDATED ARRAYS AND ANY ADDITIONAL RESULTS.')
0112      1180          FORMAT('O:EX      EXIT;  CLOSE THE OUTPUT FILE, RESTORE THE '
                        1,'VT100 TO ITS NORMAL STATE,'/9X,'AND EXIT THE PROGRAM.')
0113      1190          FORMAT('O:F :FA  FAR;  IN MANUAL MODE, SET THE FAR PICK POINT.'
                        1/9X,'IN AUTOMATIC MODE, MOVE THE FAR PICK POINT AWAY FROM THE '
                        2,'PLUME TO THE'/9X,'NEXT RELATIVE MINIMUM.')
0114      1200          FORMAT('O:FI      FILE NUMBER;  SELECT THE "FILE" OR "SHOT" '
                1,'NUMBER OF THE NEXT SHOT TO BE'/9X,'READ FROM THE SOURCE '
                2,'FILE.')
0115     1210   FORMAT('O:H :HE  HELP;  PROVIDES ASSISTANCE FOR THE USER.')
0116     1220   FORMAT('O:ID      ID HEADER;  TYPE THE HEADER INFORMATION FOR '
                1,'THE REFERENCE OR DATA SHOT,'/9X,'WHICHEVER IS SELECTED.')
0117     1230   FORMAT('O:L :LI  LIST;  PRINT THE HEADER INFORMATION AND THE '
                1,'RAW LIDAR DATA FROM EITHER'/9X,'THE REFERENCE OR DATA SHOT, '
                2,'WHICHEVER IS SELECTED.')
0118     1240   FORMAT('O:N :NE  NEAR;  IN MANUAL MODE, SET THE NEAR PICK POINT.
                1'/9X,'IN AUTOMATIC MODE, MOVE THE NEAR PICK POINT AWAY FROM '
                2,'THE PLUME TO THE'/9X,'NEXT RELATIVE MINIMUM.')
0119     1250   FORMAT('O:NO      NO REFERENCE;  A REFERENCE SHOT WILL NOT BE '
                1,'USED IN THE OPACITY'/9X,'CALCULATION.')
0120     1260   FORMAT('O:OF      OLD FILE;  TO SPECIFY AND READ IN A FILE '
                1,'CONTAINING RESULTS SO THAT'/9X,'MORE DATA MAY BE ADDED '
                2,'TO IT.')
0121     1270   FORMAT('O:O :OP  OPACITY;  CALCULATE AND DISPLAY OPACITY.')
0122     1280   FORMAT('O:OU      OUTPUT FILE;  SPECIFY A NEW OUTPUT FILE, OPEN '
                1,'IT, AND WRITE THE REPORT'/9X,'ARRAYS IN IT.  IF A FILE IS '
                2,'ALREADY OPEN, IT IS CLOSED.')
0123     1290   FORMAT('O:PK      PICK POINTS;  IN MANUAL MODE, SET BOTH PICK '
                1,'POINTS.'/9X,'IN AUTOMATIC MODE, MOVE BOTH PICK POINTS AWAY '
                2,'FROM THE PLUME TO THE'/9X,'NEXT RELATIVE MINIMA.')
0124     1300   FORMAT('O:P :PR  PRINT REPORT;  PRINT THE RESULTS IN THE '
                1,'REPORT ARRAYS ON THE LINE'/9X,'PRINTER IN SUMMARY FORM; AND,'
                2,' IF DESIRED, IN REPORT FORM.')
0125     1310   FORMAT('O:RC      RN, RF CALCULATE;  CALCULATE AND DISPLAY '
                1,'RN AND RF.')
0126     1320   FORMAT('O:R :RD  READ DATA;  READ A NEW DATA SHOT FROM THE '
                1,'SOURCE FILE.')
0127     1330   FORMAT('O:RE      REFERENCE;  REFERENCE (AMBIENT AIR) SHOT WILL '
                1,'BE USED FOR DISPLAY, ID,'/9X,'AND LIST.')
0128     1340   FORMAT('O:RR      READ REFERENCE;  READ A NEW REFERENCE SHOT '
                1,'FROM THE SOURCE FILE.')
0129     1350   FORMAT('O:RS      RESID FLAG;  CHANGES THE STATE OF THE RESID '
                1,'FLAG.  RESIDUAL PLUME'/9X,'CORRECTION TO THE OPACITY IS '
                2,'MADE OR NOT, DEPENDING ON THE STATE OF THE'/9X,'FLAG.')
0130     1360   FORMAT('O:S :SO  SOURCE;  TO SPECIFY AND OPEN A SOURCE FILE.')
0131     1370   FORMAT('O:ST      START;  TO INITIALIZE ALL PROGRAM VARIABLES '
                1,'AND FLAGS.')
0132     1380   FORMAT('O:SL      SEARCH LIMITS;  SET THE BOUNDS FOR THE '
                1,'AUTOMATIC PICK POINT SEARCH.')
0133     1390   FORMAT('O:TO      TIME REFERENCE;  SET TO, THE TIME THE LASER '
                1,'FIRES.  TO MAY BE SPECIFIED'/9X,'OR DETERMINED AUTOMATICALLY'
                2,' FROM A TO SHOT.')
0134     1400   FORMAT('O:T2      T2 FLAG;  CHANGES THE STATE OF THE T2 FLAG.  '
                1,'T-SQUARED CORRECTION IS'/9X,'EITHER PERMITTED OR SUPPRESSED,'
                2,' DEPENDING ON THE STATE OF THE FLAG.')
0135     1410   FORMAT('O:Y :YE  YES REFERENCE;  THE REFERENCE SHOT WILL BE '
                1,'USED IN OPACITY CALCULATIONS.')
0136            END
```

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FORTRAN IV-PLUS V02-51E          09:10:17     02-DEC-80           PAGE 16
OMEGSG.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                    ATTRIBUTES

   1     $CODE1  002600   704                RW,I,CON,LCL
   2     $PDATA  000164    58                RW,D,CON,LCL
   3     $IDATA  011734  2542                RW,D,CON,LCL
   4     $VARS   000010     4                RW,D,CON,LCL
   6     .$$$$.  000002     1                RW,D,OVR,GBL
   7     COMMAN  000146    51                RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 HELP         1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 I      I*2   4-000006    IC     I*2   4-000002    IU     I*2   4-000004    IWSTAT I*2   4-000000    VT100  L*1   6-000000

ARRAYS

 NAME   TYPE  ADDRESS       SIZE        DIMENSIONS

 ICOM   I*2   7-000000  000146     51   (51)

LABELS

 LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS           LABEL  ADDRESS

 5      1-000156          10        **             20     1-000320          30     1-000374          40     1-000430
 50     1-000470          60     1-000530          70     1-000570          80     1-000630          90     1-000670
 100    1-000730          110    1-000770          120    1-001030          130    1-001070          140    1-001130
 150    1-001170          160    1-001230          170    1-001270          180    1-001330          190    1-001370
 200    1-001430          210    1-001470          220    1-001530          230    1-001570          240    1-001630
 250    1-001670          260    1-001730          270    1-001770          280    1-002030          290    1-002070
 300    1-002130          310    1-002170          320    1-002230          330    1-002270          340    1-002330
 350    1-002370          360    1-002430          370    1-002470          380    1-002530          390    1-002576
 1000'  3-000000          1010'  3-000006          1020'  3-000060          1030'  3-001252          1040'  3-001442
 1050'  3-001446          1060'  3-001520          1070'  3-001640          1080'  3-002062          1090'  3-002316
 1100'  3-002420          1110'  3-002532          1120'  3-003104          1130'  3-003310          1140'  3-003416
 1150'  3-003576          1160'  3-003700          1170'  3-004002          1180'  3-004602          1190'  3-004756
 1200'  3-005216          1210'  3-005404          1220'  3-005470          1230'  3-005650          1240'  3-006066
 1250'  3-006332          1260'  3-006470          1270'  3-006656          1280'  3-006742          1290'  3-007164
 1300'  3-007432          1310'  3-007452          1320'  3-007754          1330'  3-010060          1340'  3-010222
 1350'  3-010340          1360'  3-010610          1370'  3-010700          1380'  3-011004          1390'  3-011126
 1400'  3-011336          1410'  3-011572
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FORTRAN IV-PLUS V02-51E          09:10:17    02-DEC-80            PAGE 17
OMEG5G.FTN       /TR:BLOCKS/WR

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   WAIT

TOTAL SPACE ALLOCATED = 015100  3360

NO FPP INSTRUCTIONS GENERATED

SYO:[101,1]OMEG5G,SYO:[101,1]OMEG5G/-SP=SYO:[101,1]OMEG5G/CO:77
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FORTRAN IV-PLUS V02-51          14:31:56    04-SEP-80          PAGE 1
OMEG5H.FTN        /TR:BLOCKS/WR

0001                  SUBROUTINE PRINT
             C
             C        PRINT RESULTS TO DATE ON THE LINE PRINTER
             C
0002                  BYTE VT100,OUT,BDAT(9),AVE
0003                  COMMON VT100
0004                  COMMON /REPORT/REP(14,136),IREP(12,136)
0005                  COMMON /NPC/NOPAC,NOPAC1,NOPAC2,OUT
0006                  COMMON /AUXIL/IAUX(52,3)
0007                  COMMON /AVGE/SAVE,AVE
0008                  DIMENSION ISCR(20),SCR(20),TITLE(33)
0009                  IF(VT100)CALL ERLINE
             C
             C        IF THERE IS NO DATA IN THE ARRAYS, DON'T BOTHER
             C
0010                  IF(NOPAC.LT.NOPAC1)RETURN
             C
             C        PRINT HEADER INFORMATION
             C
0011                  A=.001*IAUX(12,1)
0012                  B=.1*IAUX(15,1)
0013                  C=.1*IAUX(18,1)
0014                  AZ=.1*IAUX(19,1)
0015                  EL=.1*IAUX(20,1)
0016                  CALL DATE(BDAT) !GET TODAY'S DATE
             C
             C        GET THE NAME OF THE OPERATOR
             C
0017                  WRITE(5,2490)
0018                  READ(5,2030)ISCR
0019                  IF(VT100)CALL ERLINE
             C
             C        GET VIOLATION VALUES FOR AVERAGE AND SINGLE EVENT
             C
0020                  WRITE(5,2510)
0021                  READ(5,*)VAVE,VSIN
0022                  L=1
             C
             C        PRINT THE INFORMATION IN THE REPORT ARRAYS FOR EACH SHOT THIRTEEN
             C        SHOTS PER PAGE, INDICATING WHEN A VIOLATION HAS OCCURRED
             C
0023                  DO 1170 I=NOPAC1,NOPAC
0024                  IF(L.GT.1)GOTO 1140
0025                  WRITE(6,2480)
0026                  WRITE(6,2600)(IAUX(M,1),M=21,52)
0027                  IF(IAUX(10,1).EQ.'LO')WRITE(6,2610)
0028                  IF(IAUX(10,1).EQ.'LI')WRITE(6,2620)
0029                  IF(IAUX(10,1).EQ.'T2')WRITE(6,2630)
0030                  WRITE(6,2640)IAUX(11,1),A
0031                  WRITE(6,2650)B,IAUX(13,1),IAUX(14,1),C,IAUX(16,1),IAUX(17,1)
                     1,IAUX(9,1),AZ,EL
0032                  WRITE(6,2500)BDAT,ISCR
0033        1140      WRITE(6,2520)(IREP(M,I),M=1,8)
0034                  WRITE(6,2530)IREP(9,I),(REP(M,I),M=1,4),IREP(10,I),
                     1(REP(M,I),M=5,8)
0035                  WRITE(6,2540)REP(9,I),REP(11,I),REP(10,I),REP(14,I),IREP(11,I),
                 1REP(12,I),IREP(12,I),REP(13,I)
                 IF(REP(11,I).LT.8.5)GOTO 1150
                 WRITE(6,2550)
                 GOTO 1160
        1150     IF(REP(10,I).GE.VSIN)WRITE(6,2560)
        1160     IF(REP(12,I).GE.VAVE)WRITE(6,2570)
                 IF(REP(13,I).GE.8.5)WRITE(6,2580)
                 L=L+1
                 IF(L.GT.13)L=1
        1170     CONTINUE
        C
        C        CALCULATE AND PRINT THE AVERAGE STANDARD DEVIATION AND OPACITY FOR
        C        ALL THE SHOTS IN THE REPORT
        C
                 SUM=0.0
                 SIGSUM=0.0
                 M=0
                 DO 1180 I=NOPAC1,NOPAC
                 SIGSUM=SIGSUM+REP(11,I)
                 IF(REP(11,I).GE.8.5)GOTO 1180
                 SUM=SUM+REP(10,I)
                 M=M+1
        1180     CONTINUE
                 SUM=SUM/M
                 SIGSUM=SIGSUM/NOPAC2
                 WRITE(6,2590)M,SUM,NOPAC2,SIGSUM
                 IF(VT100)CALL ERLINE
        C
        C        FIND OUT IF A REPORT IS NEEDED
        C
                 WRITE(5,2595)
                 READ(5,2080)IC
                 IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 1240
        C
        C        A REPORT IS NEEDED, GET THE TITLE
        C
                 IF(VT100)GOTO 1190
                 WRITE(5,2660)
                 READ(5,2670)TITLE
                 GOTO 1200
        1190     CALL ERLINE
                 WRITE(5,2660)
                 CALL WAIT(2,2,IWSTAT)
                 CALL ERLINE
                 WRITE(5,2680)
                 READ(5,2690)TITLE
        C
        C        PRINT THE REPORT, 50 SHOTS PER PAGE
        C
        1200     L=1
                 DO 1230 I=NOPAC1,NOPAC
                 IF(L.GT.1)GOTO 1210
                 WRITE(6,2700)
                 WRITE(6,2710)TITLE
                 WRITE(6,2720)
        1210     IF(REP(11,I).GE.8.5)GOTO 1230
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              A=0.0
              B=0.0
              M1=0
              M2=0
              C=REP(10,I)
              D=REP(11,I)
              IF(C.LT.0.0)C=0.0
              IF(REP(14,I)+.20.LT.SAVE)GOTO 1220
              A=REP(12,I)
              B=REP(13,I)
              M1=IREP(12,I)-IREP(11,I)
              M2=IREP(12,I)
      1220    ENCODE(19,2360,SCR)A,B
              DECODE(19,2365,SCR)IA,IB
              ENCODE(19,2360,SCR)C,D
              DECODE(19,2365,SCR)IC,IE
              WRITE(6,2730)(IREP(M,I),M=1,6),IC,IE,IA,IB,M1,M2
              IF(REP(10,I).GE.VSIN)WRITE(6,2740)
              IF(A.GE.VAVE)WRITE(6,2750)
              L=L+1
              IF(L.GT.50)L=1
      1230    CONTINUE
      1240    CALL CLOSE(6)
              IF(VT100)CALL ERLINE
              RETURN
      2030    FORMAT(20A2)
      2080    FORMAT(A2)
      2360    FORMAT(1X,F9.0,F9.0)
      2365    FORMAT(I9,1X,I8)
      2480    FORMAT(1H1,'UNITED STATES ENVIRONMENTAL PROTECTION AGENCY,',
              1' NATIONAL ENFORCEMENT INVESTIGATIONS CENTER,',
              2'  DENVER, COLORADO 80225'/)
      2490    FORMAT(1H$,16X,'TYPE YOUR NAME:  ')
      2500    FORMAT(/' OMEGA-1 LIDAR OPACITY DATA.   ANALYZED ',9A1,
              1' BY ',20A2/)
      2510    FORMAT(1H$,16X,'ENTER VIOLATION VALUES FOR AVERAGE,',
              1' SINGLE EVENT:  ')
      2520    FORMAT(/I3,'/',I2,'/',I2,I4,':',I2,':',I2,'  FILE',I5,
              1'  REF FILE',I5)
      2530    FORMAT(' TN=',I5,'  XN=',F6.1,' +OR- ',F4.1,' RN=',F6.1,' +OR- '
              1,F4.1,'   TF=',I5,'  XF=',F6.1,' +OR- ',F4.1,' RF=',F6.1,
              2' +OR- ',F4.1)
      2540    FORMAT(' OP=',F5.1,'% +OR- ',F4.1,11X,'OPC=',F5.1,'%  FOR',F6.2
              1,' MINUTES',I4,' OP''S AVE',F6.1,'%',11X,I3,' STD DEV''S AVE',
              2F5.1)
      2550    FORMAT(1H+,20X,'TOO NOISY')
      2560    FORMAT(1H+,20X,'VIOLATION')
      2570    FORMAT(1H+,80X,'VIOLATION')
      2580    FORMAT(1H+,113X,'TOO NOISY')
      2590    FORMAT(/I5,' OPACITIES AVERAGE',F6.1,10X,I4,
              1' STANDARD DEVIATIONS AVERAGE',F5.1)
      2595    FORMAT(1H$,16X,'SHOULD A REPORT BE PRINTED? ')
      2600    FORMAT(1X,32A2)
      2610    FORMAT(1H+,T69,'LOG CHANNEL,')
      2620    FORMAT(1H+,T69,'LINEAR CHANNEL,')
      2630    FORMAT(1H+,T69,'T-SQUARED CHANNEL,')
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FORTRAN IV-PLUS V02-51          14:31:56    04-SEP-80          PAGE 4
OMEG5H.FTN          /TR:BLOCKS/WR

0124     2640     FORMAT(1H+,T89,I5,' NS/PT, +OR-',F5.2,' VOLTS')
0125     2650     FORMAT(' GATE 1',F5.1,' DB',I6,' TO',I6,' NS,  GATE 2',F5.1
                  1,' DB',I6,' TO',I6,' NS,  CALIBRATION FILE',I5,',   AZ=',F5.1,
                  2',  EL=',F4.1/)
0126     2660     FORMAT(17X,'ENTER TITLE.  132 CHARACTERS MAXIMUM.')
0127     2670     FORMAT(20A4/13A4)
0128     2680     FORMAT(1H$)
0129     2690     FORMAT(33A4)
0130     2700     FORMAT(1H1,44X,'UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'
                  1/46X,'NATIONAL ENFORCEMENT INVESTIGATIONS CENTER'
                  2/56X,'DENVER, COLORADO 80225'//)
0131     2710     FORMAT(1X,33A4/)
0132     2720     FORMAT(8X,'DATE',6X,'TIME',4X,'OPACITY   SO  VIOLATION',
                  1'  AVERAGE OPACITY  AVERAGE SO  VIOLATION  NUMBER DISCARDED'/)
0133     2730     FORMAT(6X,I2,'/',I2,'/',I2,I4,':',I2,':',I2,3X,I4,4X,I3
                  1,18X,I4,11X,I3,20X,I3,' OF',I4)
0134     2740     FORMAT(1H+,T43,'****')
0135     2750     FORMAT(1H+,T83,'****')
0136              END
```

```
FORTRAN IV-PLUS V02-51           14:31:56     04-SEP-80          PAGE 5
OMEG5H.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                     ATTRIBUTES

   1     $CODE1   003724  1002                RW,I,CON,LCL
   2     $PDATA   000024    10                RW,D,CON,LCL
   3     $IDATA   002452   661                RW,D,CON,LCL
   4     $VARS    000502   161                RW,D,CON,LCL
   5     $TEMPS   000006     3                RW,D,CON,LCL
   6     .$$$$.   000002     1                RW,D,OVR,GBL
   7     REPORT   025200  5440                RW,D,OVR,GBL
   8     NPC      000010     4                RW,D,OVR,GBL
   9     AUXIL    000470   156                RW,D,OVR,GBL
  10     AVGE     000006     3                RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 PRINT         1-000000

VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 A       R*4   4-000406    AVE     L*1  10-000004    AZ      R*4   4-000422    B       R*4   4-000412    C       R*4   4-000416
 D       R*4   4-000470    EL      R*4   4-000426    I       I*2   4-000444    IA      I*2   4-000474    IB      I*2   4-000476
 IC      I*2   4-000460    IE      I*2   4-000500    IWSTAT  I*2   4-000462    L       I*2   4-000442    M       I*2   4-000446
 M1      I*2   4-000464    M2      I*2   4-000466    NOPAC   I*2   8-000000    NOPAC1  I*2   8-000002    NOPAC2  I*2   8-000004
 OUT     L*1   8-000006    SAVE    R*4  10-000000    SIGSUM  R*4   4-000454    SUM     R*4   4-000450    VAVE    R*4   4-000432
 VSIN    R*4   4-000436    VT100   L*1   6-000000

ARRAYS

 NAME    TYPE  ADDRESS         SIZE         DIMENSIONS

 BDAT    L*1   4-000000  000011     4       (9)
 IAUX    I*2   9-000000  000470   156       (52,3)
 IREP    I*2   7-016700  006300  1632       (12,136)
 ISCR    I*2   4-000012  000050    20       (20)
 REP     R*4   7-000000  016700  3808       (14,136)
 SCR     R*4   4-000062  000120    40       (20)
 TITLE   R*4   4-000202  000204    66       (33)

LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 1140    1-001030          1150    1-001526          1160    1-001602          1170      **              1180    1-002072
 1190    1-002426          1200    1-002554          1210    1-002712          1220    1-003110          1230    1-003640
 1240    1-003666          2030'   3-000000          2080'   3-000004          2360'   3-000010          2365'   3-000020
 2480'   3-000026          2490'   3-000222          2500'   3-000252          2510'   3-000342          2520'   3-000436
```

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FORTRAN IV-PLUS V02-51          14:31:56    04-SEP-80          PAGE 6
OMEG5H.FTN       /TR:BLOCKS/WR

 2530'   3-000514      2540'   3-000662      2550'   3-001022      2560'   3-001042      2570'   3-001062
 2580'   3-001102      2590'   3-001122      2595'   3-001222      2600'   3-001266      2610'   3-001274
 2620'   3-001320      2630'   3-001346      2640'   3-001400      2650'   3-001440      2660'   3-001614
 2670'   3-001666      2680'   3-001676      2690'   3-001702      2700'   3-001706      2710'   3-002106
 2720'   3-002114      2730'   3-002266      2740'   3-002350      2750'   3-002364

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   DATE    ERLINE  WAIT

TOTAL SPACE ALLOCATED = 035042  7441

SYO:[101,1]OMEG5H,SYO:[101,1]OMEG5H/-SP=SYO:[101,1]OMEG5H
```

B(c) Omega-6 Lidar Data Output File Editor Program (FORTRAN-4+)

```
FORTRAN IV-PLUS V02-51E          14:47:13    02-DEC-80          PAGE 1
OMEGA6.FTN          /TR:BLOCKS/WR

              PROGRAM OMEGA6
      C
      C       THIS PROGRAM IS USED TO EDIT LIDAR OPACITY DATA GENERATED BY OMEGA5.
      C       EDITING CAPABILITIES ARE LIMITED TO ACCEPTING OR DELETING DATA ON A
      C       SHOT BY SHOT BASIS.
      C       THE PROGRAM ALSO HAS THE CAPABILITY OF MERGING TWO OR MORE INPUT FILES
      C       INTO ONE OUTPUT FILE, AND THE CAPABILITY OF RECALCULATING RUNNING
      C       AVERAGES USING ONLY THE ACCEPTED DATA.
      C
      C       INPUT FILES CAN BE NO BIGGER THAN 140 SHOTS.  OUTPUT FILES UP TO
      C       360 SHOTS IN LENGTH CAN BE CREATED.
      C
              BYTE AV, IC
              COMMON IAUX(52),REP(14,140),IREP(12,140),ISCNT,ISHOT,JSHOT,ICNT
              DIMENSION REPO(14,360),IREPO(12,360),IOFILE(10)
              KMAX=360          !MAXIMUM NUMBER OF SHOTS PERMITTED IN THE OUTPUT FILE
              ISCNT=1           !INPUT FILE COUNTER
              AVE=0.0           !AVERAGING INTERVAL IN MINUTES
              NAVE=0            !NUMBER OF OPACITIES IN THE RUNNING AVERAGE
              AV=.FALSE.        !DATA WILL NOT BE AVERAGED
              ISHOT=0           !NUMBER OF LAST SHOT ACCEPTED OR REJECTED
      C
      C       GET FIRST SOURCE FILE AND READ DATA INTO INPUT ARRAYS
      C
              CALL SOURCE
              JCNT=1            !INPUT ARRAY INDEX
              KCNT=1            !OUTPUT ARRAY INDEX
      C
      C       IF THERE ARE NO SHOTS IN THE INPUT ARRAY, EXIT
      C
              IF(ICNT.EQ.0)CALL EXIT
              WRITE(5,1000)    !WILL RUNNING AVERAGE BE CALCULATED?
              READ(5,1010)IC
              IF(IC.NE.'Y')GOTO 10
      C
      C       YES, SET AV FLAG AND GET AVERAGING INTERVAL
      C
              AV=.TRUE.
              WRITE(5,1020)
              READ(5,*)AVE
      C
      C       TELL OPERATOR THE NUMBER OF THE NEXT SHOT IN THE INPUT FILE AND
      C       GET THE NEXT COMMAND
      C
      10      WRITE(5,1030)IREP(7,JCNT)
              READ(5,1010,END=15)IC
              IF(IC.EQ.'R')GOTO 20      !REJECT COMMAND
              IF(IC.EQ.'N')GOTO 40      !NEW SOURCE FILE
              IF(IC.EQ.'A')GOTO 50      !ACCEPT DATA
              IF(IC.EQ.'W')GOTO 150     !WRITE DATA IN AN OUTPUT FILE
      C
      C       IF INPUT COMMAND IS INVALID, GET A NEW COMMAND
      C
              GOTO 10
      C
      C       AN END OF FILE OR CONTROL 'Z' WAS TYPED TO INDICATE THE END OF THE
```

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FORTRAN IV-PLUS V02-51E          14:47:13    02-DEC-80          PAGE 2
OMEGA6.FTN       /TR:BLOCKS/WR

           C        PROGRAM
           C
0028       15       CALL EXIT
           C
           C        ENTRY POINT FOR REJECT COMMAND
           C        SHOTS WILL BE REJECTED THROUGH SHOT NUMBER N.  IF THERE ARE TWO SHOTS
           C        IN THE INPUT FILE NUMBERED N, ONLY THE FIRST IS REJECTED.
           C
0029       20       WRITE(5,1040)
0030                READ(5,*)N
0031                IF(N.LE.JSHOT)GOTO 25
           C
           C        THE SHOT NUMBER SPECIFIED IS BIGGER THAN THE LAST SHOT IN THE INPUT FILE
           C        NOTIFY THE OPERATOR AND VERIFY THAT N IS CORRECT
           C
0032                WRITE(5,1050)N,JSHOT
0033                READ(5,1010)IC
0034                IF(IC.NE.'Y')GOTO 20
0035       25       IF(N.NE.IREP(7,JCNT))GOTO 30
0036                JCNT=JCNT+1
0037                GOTO 10
           C
           C        THREE PREVIOUS STATEMENTS ADDED 7/7/80 FOR ONE SHOT DELETION
           C
0038       30       IF(N.GT.IREP(7,JCNT-1))GOTO 35
0039                ISHOT=IREP(7,JCNT-1)
0040                GOTO 10
0041       35       JCNT=JCNT+1
0042                IF(JCNT.LE.ICNT)GOTO 30
0043                JCNT=JCNT-1
0044                ISHOT=IREP(7,JCNT)
0045                WRITE(5,1060)ISHOT
0046                GOTO 10
           C
           C        ENTRY POINT FOR NEW SOURCE FILE COMMAND
           C
0047       40       CALL SOURCE
0048                JCNT=1
0049                IF(ICNT.EQ.0)CALL EXIT
0050                GOTO 10
           C
           C        ENTRY POINT FOR ACCEPT COMMAND
           C        DATA IS ACCEPTED THROUGH SHOT NUMBER N.  IF THERE ARE TWO SHOTS NUMBERED
           C        N, ONLY THE FIRST IS ACCEPTED.  AS DATA IS ACCEPTED, A RUNNING AVERAGE
           C        IS CALCULATED IF ONE HAS BEEN SPECIFIED.
           C
0051       50       WRITE(5,1070)
0052                READ(5,*)N
0053                IF(N.LE.JSHOT)GOTO 60
           C
           C        N IS GREATER THAN JSHOT, THE LAST SHOT IN THE INPUT FILE.  NOTIFY THE
           C        OPERATOR AND VERIFY.
           C
0054                WRITE(5,1050)N,JSHOT
0055                READ(5,1010)IC
0056                IF(IC.NE.'Y')GOTO 50
```

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FORTRAN IV-PLUS V02-51E          14:47:13    02-DEC-80           PAGE 3
OMEGA6.FTN          /TR:BLOCKS/WR

0057     60       IF(KCNT.LE.KMAX)GOTO 70
          C
          C       THE OUTPUT FILE IS FULL.  NOTIFY THE OPERATOR AND GET A NEW COMMAND
          C
0058              WRITE(5,1080)IREPO(7,KCNT-1)
0059              GOTO 10
0060     70       I=KCNT
0061              IF(I.GT.1)GOTO 80
          C
          C       THIS IS THE FIRST SHOT IN THE OUTPUT FILE.  INITIALIZE ACCUMULATORS
          C       AND TIME FOR THE RUNNING AVERAGE.
          C
0062              NAVE=0
0063              SAVEC=0.0
0064              NSIG=0
0065              OPSUM=0.0
0066              OSIGSM=0.0
0067              STIM=IREP(4,JCNT)*60.0+IREP(5,JCNT)+IREP(6,JCNT)/60.0
0068              ITCNT=I
0069     80       IF(AV)GOTO 90
          C
          C       A RUNNING AVERAGE IS NOT BEING CALCULATED
          C
0070              STIM=0.0
0071              ITCNT=0
          C
          C       COPY EVERYTHING BUT RUNNING AVERAGE INFORMATION FOR CURRENT SHOT
          C       FROM THE INPUT FILE TO THE OUTPUT FILE.
          C
0072     90       DO 100 L=1,10
0073              IREPO(L,I)=IREP(L,JCNT)
0374              REPO(L,I)=REP(L,JCNT)
0075    100       CONTINUE
0076              REPO(11,I)=REP(11,JCNT)
0077              IREPO(11,I)=0
0078              IREPO(12,I)=0
0079              REPO(12,I)=0.0
0080              REPO(13,I)=0.0
0081              REPO(14,I)=0.0
0082              IF(.NOT.AV)GOTO 120
          C
          C       CALCULATE THE NEW RUNNING AVERAGE
          C
0083              TIME=IREP(4,JCNT)*60.0+IREP(5,JCNT)+IREP(6,JCNT)/60.0
          C
          C       MIDNIGHT CORRECTION
          C
0084              IF(TIME.LT.STIM)TIME=TIME+1440.
0085    110       IF(STIM+AVE.LT.TIME)GOTO 140
          C
          C       ADD THE CURRENT VALUE OF SO TO THE RUNNING AVERAGE
          C
0086              NSIG=NSIG+1
0087              OSIGSM=OSIGSM+REP(11,JCNT)
0088              REPO(13,I)=OSIGSM/NSIG
0089              IREPO(12,I)=NSIG
```

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FORTRAN IV-PLUS V02-51E         14:47:13    02-DEC-80           PAGE 4
OMEGA6.FTN       /TR:BLOCKS/WR

0090                    SAVEC=TIME-STIM
0091                    REPO(14,I)=SAVEC
0092                    IREPO(11,I)=NAVE
0093                    IF(NAVE.GT.0)REPO(12,I)=OPSUM/NAVE
              C
              C         ADD THE CURRENT VALUE OF OPACITY TO THE RUNNING AVERAGE IF SO IS
              C         8 OR LESS.  (FIGURED TO THE NEAREST INTEGER)
              C
0094                    IF(REP(11,JCNT).GE.8.5)GOTO 120
0095                    NAVE=NAVE+1
0096                    OPSUM=OPSUM+REP(10,JCNT)
0097                    IREPO(11,I)=NAVE
0098                    REPO(12,I)=OPSUM/NAVE
              C
              C         INCREMENT INPUT AND OUTPUT ARRAY INDICES
              C
0099          120       JCNT=JCNT+1
0100                    KCNT=KCNT+1
0101                    IF(JCNT.LE.ICNT)GOTO 130
              C
              C         THE INPUT ARRAY IS EMPTY.  TELL OPERATOR AND GET NEW COMMAND
              C
0102                    JCNT=JCNT-1
0103                    ISHOT=IREP(7,JCNT)
0104                    WRITE(5,1060)ISHOT
0105                    GOTO 10
              C
              C         CHECK TO SEE IF ENOUGH SHOTS HAVE BEEN ACCEPTED, AND GET NEW COMMAND
              C         IF SO.
              C
0106          130       IF(N.EQ.IREP(7,JCNT-1))GOTO 10
              C
              C         NOT DONE YET, CONTINUE
              C
0107                    ISHOT=IREP(7,JCNT-1)
0108                    GOTO 60
              C
              C         VALUES NEED TO BE SUBTRACTED FROM THE RUNNING AVERAGE
              C
0109          140       NSIG=NSIG-1
              C
              C         SUBTRACT FIRST SO FROM THE RUNNING AVERAGE
              C
0110                    OSIGSM=OSIGSM-REPO(11,ITCNT)
0111                    ITCNT=ITCNT+1
0112                    STIM=IREPO(4,ITCNT)*60.0+IREPO(5,ITCNT)+IREPO(6,ITCNT)/60.0
0113                    IF(STIM+1440.0.LE.TIME)TIME=TIME-1440.
0114                    IF(REPO(11,ITCNT-1).GE.8.5)GOTO 110
              C
              C         IF THE VALUE OF SO JUST SUBTRACTED WAS 8 OR LESS, SUBTRACT THE
              C         CORRESPONDING VALUE OF OPACITY FROM THE RUNNING AVERAGE
              C
0115                    NAVE=NAVE-1
0116                    OPSUM=OPSUM-REPO(10,ITCNT-1)
0117                    GOTO 110
              C
```

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FORTRAN IV-PLUS V02-51E         14:47:13     02-DEC-80            PAGE 5
OMEGA6.FTN        /TR:BLOCKS/WR

             C          ENTRY POINT FOR WRITE OUTPUT FILE COMMAND
             C          GET THE OUTPUT FILE SPECIFICATION, OPEN THE FILE, AND WRITE THE
             C          DATA FROM THE OUTPUT ARRAYS INTO IT.
             C          MOVE THE DATA FROM THE CURRENT RUNNING AVERAGE FROM THE END OF THE
             C          OUTPUT ARRAYS TO THE BEGINNING.
             C
0118         150        WRITE(5,1090)
0119                    READ(5,1100)IOFILE
0120                    IOFILE(10)=0
0121                    CALL CLOSE(4)
0122                    OPEN(UNIT=4,NAME=IOFILE,ERR=160,DISPOSE='SAVE')
0123                    GOTO 170
0124         160        WRITE(5,1110)
0125                    GOTO 150
0126         170        WRITE(4,1120)IAUX
0127                    DO 180  I=1,KCNT-1
0128                    WRITE(4,1130)(IREPO(J,I),J=1,12),(REPO(J,I),J=1,14)
0129         180        CONTINUE
0130                    CALL CLOSE(4)
0131                    IF(KCNT.LE.IREPO(12,KCNT))GOTO 10
             C
             C          IF THE PRECEDING STATEMENT IS TRUE, ALL DATA IN THE OUTPUT ARRAYS IS
             C          NEEDED FOR THE CURRENT RUNNING AVERAGE
             C
0132                    N=ITCNT-1
0133                    KCNT=KCNT-ITCNT+1
             C
             C          MOVE DATA FOR THE CURRENT RUNNING AVERAGE FROM THE END OF THE REPORT
             C          ARRAYS TO THE BEGINNING.
             C
0134                    DO 200  I=1,KCNT-1
0135                    DO 190 II=1,12
0136                    IREPO(II,I)=IREPO(II,I+N)
0137                    REPO(II,I)=REPO(II,I+N)
0138         190        CONTINUE
0139                    REPO(13,I)=REPO(13,I+N)
0140                    REPO(14,I)=REPO(14,I+N)
0141         200        CONTINUE
0142                    GOTO 10
             C
             C          FORMAT STATEMENTS
             C
0143         1000       FORMAT('$WILL DATA BE AVERAGED? ')
0144         1010       FORMAT(A1)
0145         1020       FORMAT('$ENTER AVERAGING INTERVAL IN MINUTES: ')
0146         1030       FORMAT(1X,I4,' IS THE NEXT SHOT'/'$:')
0147         1040       FORMAT('$REJECT THROUGH SHOT: ')
0148         1050       FORMAT(1X,I4,' IS GREATER THAN',I5,', THE LAST SHOT IN THE ',
                        1'INPUT FILE.'/'$ARE YOU SURE? ')
0149         1060       FORMAT(' THE SOURCE FILE IS EMPTY.  LAST SHOT WAS',I5)
0150         1070       FORMAT('$ACCEPT THROUGH SHOT: ')
0151         1080       FORMAT(' OUTPUT ARRAY IS FULL.  LAST SHOT IN ARRAY IS',I5)
0152         1090       FORMAT('$ENTER OUTPUT FILE SPECIFICATION: ')
0153         1100       FORMAT(20A2)
0154         1110       FORMAT(' ERROR OPENING DISC FILE!')
0155         1120       FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
```

```
0156      1130      FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
0157                END
```

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FORTRAN IV-PLUS V02-51E          14:47:13    02-DEC-80          PAGE 7
OMEGA6.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER    NAME         SIZE                    ATTRIBUTES

   1     $CODE1   003656    983                RW,I,CON,LCL
   2     $PDATA   000004      2                RW,D,CON,LCL
   3     $IDATA   000750    244                RW,D,CON,LCL
   4     $VARS    070304  14434                RW,D,CON,LCL
   5     $TEMPS   000010      4                RW,D,CON,LCL
   6     .$$$$.   026060   5656                RW,D,OVR,GBL

VARIABLES

 NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 AV     L*1   4-000000   AVE    R*4   4-070230   I      I*2   4-070244   IC     L*1   4-000001   ICNT   I*2   6-026056
 II     I*2   4-070302   ISCNT  I*2   6-026050   ISHOT  I*2   6-026052   ITCNT  I*2   4-070270   J      I*2   4-070300
 JCNT   I*2   4-070236   JSHOT  I*2   6-026054   KCNT   I*2   4-070240   KMAX   I*2   4-070226   L      I*2   4-070272
 N      I*2   4-070242   NAVE   I*2   4-070234   NSIG   I*2   4-070252   OPSUM  R*4   4-070254   OSIGSM R*4   4-070260
 SAVEC  R*4   4-070246   STIM   R*4   4-070264   TIME   R*4   4-070274

ARRAYS

 NAME   TYPE  ADDRESS         SIZE        DIMENSIONS

 IAUX   I*2   6-000000   000150     52    (52)
 IOFILE I*2   4-070202   000024     10    (10)
 IREP   I*2   6-017410   006440   1680    (12,140)
 IREPO  I*2   4-047302   020700   4320    (12,360)
 REP    R*4   6-000150   017240   3920    (14,140)
 REPO   R*4   4-000002   047300  10080    (14,360)

LABELS

 LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 10      1-000260         15      1-000444         20      1-000462         25      1-000644         30      1-000702
 35      1-000742         40      1-001042         50      1-001110         60      1-001272         70      1-001356
 80      1-001504         90      1-001532         100        **            110     1-002100         120     1-002342
 130     1-002446         140     1-002512         150     1-002730         160     1-003034         170     1-003064
 180        **            190        **            200        **            1000'   3-000000         1010'   3-000034
 1020'   3-000040         1030'   3-000112         1040'   3-000146         1050'   3-000200         1060'   3-000320
 1070'   3-000376         1080'   3-000430         1090'   3-000512         1100'   3-000560         1110'   3-000564
 1120'   3-000620         1130'   3-000656

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE    EXIT    OPEN$    SOURCE

TOTAL SPACE ALLOCATED = 123226 21323
```

```
              SUBROUTINE SOURCE
C
C             THIS SUBROUTINE READS DATA FROM A DESIGNATED DISC FILE
C             INTO REP AND IREP
C
              COMMON IAUX(52),REP(14,140),IREP(12,140),ISCNT,ISHOT,JSHOT,ICNT
              DIMENSION ISFILE(10)
C
C             GET THE INPUT FILE SPECIFICATION FOR INPUT FILE NUMBER ISCNT
C
10            WRITE(5,1000)ISCNT
              READ(5,1010)ISFILE
              IF(ISFILE(2).EQ.'  ')GOTO 120
              ISFILE(10)=0
              CALL CLOSE(3)
              OPEN(UNIT=3,NAME=ISFILE,TYPE='OLD',READONLY,ERR=20
              1,DISPOSE='SAVE')
              GOTO 30
C
C             HERE IF ERROR OPENING THE DISC FILE
C
20            WRITE(5,1020)
              GOTO 10
C
C             READ HEADER INFORMATION
C
30            READ(3,1030)IAUX
C
C             DISPLAY THE HEADER INFORMATION ON THE TERMINAL
C
              WRITE(5,1040)IAUX(7),(IAUX(I),I=1,6),IAUX(8),IAUX(9)
              WRITE(5,1050)(IAUX(I),I=21,52)
C
C             READ DATA INTO THE INPUT ARRAYS
C
              DO 40 I=1,140
              READ(3,1060,END=50)(IREP(L,I),L=1,12),(REP(L,I),L=1,14)
40            CONTINUE
50            CALL CLOSE(3)
              ICNT=I-1         !NUMBER OF SHOTS IN THE INPUT FILE
C
C             TELL THE OPERATOR WHICH SHOTS ARE INCLUDED IN THIS FILE
C             AND VERIFY THAT THIS IS THE CORRECT FILE
C
              WRITE(5,1070)ISHOT,IREP(7,1),IREP(7,ICNT)
              READ(5,1010)IC
              IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
              IF(ISCNT.EQ.1)GOTO 60
C
C             CHECK TO SEE THAT THIS FILE INCLUDES THE NEXT SHOT.  IF IT DOES NOT
C             TELL THE OPERATOR, AND VERIFY THAT THIS IS THE CORRECT FILE.
C
              IF(IREP(7,1).LE.ISHOT+1.AND.IREP(7,ICNT).GE.ISHOT+1)GOTO 60
              WRITE(5,1080)
              READ(5,1010)IC
              IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
```

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FORTRAN IV-PLUS V02-51E         14:47:23    02-DEC-80          PAGE 9
OMEGA6.FTN          /TR:BLOCKS/WR

        60      ISCNT=ISCNT+1
        C
        C       IF THIS IS THE FIRST FILE, KEEP ALL THE DATA
        C
                IF(ISCNT.EQ.2)GOTO 110
                IF(ISHOT.LT.IREP(7,1))GOTO 110
        C
        C       IF THIS IS NOT THE FIRST INPUT FILE, KEEP ONLY THE DATA WHICH HAS
        C       NOT ALREADY BEEN ACCEPTED OR REJECTED.
        C
                DO 70 I=1,ICNT
                IF(ISHOT.EQ.IREP(7,I))GOTO 80
        70      CONTINUE
                I=I-1
        80      DO 100 J=1,ICNT-I
                DO 90 K=1,12
                IREP(K,J)=IREP(K,J+I)
                REP(K,J)=REP(K,J+I)
        90      CONTINUE
                REP(13,J)=REP(13,J+I)
                REP(14,J)=REP(14,J+I)
        100     CONTINUE
                ICNT=ICNT-I
        110     JSHOT=IREP(7,ICNT)
                RETURN
        C
        C       NO INPUT FILE WAS SPECIFIED.  VERIFY THAT NO NEW FILE IS DESIRED,
        C       AND RETURN WITH THE FILE SIZE SET TO 0.
        C
        120     WRITE(5,1090)
                READ(5,1010)IC
                IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
                ICNT=0
                RETURN
        C
        C       FORMAT STATEMENTS
        C
        1000    FORMAT(' ENTER FILE SPECIFICATION FOR SOURCE FILE NUMBER',I3,1X)
        1010    FORMAT(20A2)
        1020    FORMAT(' ERROR OPENING DISC FILE!')
        1030    FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
        1040    FORMAT(/' FILE',I5,I4,'/',I2,'/',I2,I4,':',I2,':',I2,2X,
                1'REF. FILE',I5,2X,'GATE CALIBRATION FILE',I5/)
        1050    FORMAT(1X,32A2/)
        1060    FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
        1070    FORMAT(' LAST SHOT WAS:',I5,'  THIS FILE STARTS AT SHOT',I5,
                1' AND RUNS TO SHOT',I5/'$IS THIS THE RIGHT FILE? ')
        1080    FORMAT('$THIS FILE DOES NOT INCLUDE THE NEXT SHOT.',
                1'  ARE YOU SURE IT''S THE RIGHT ONE? ')
        1090    FORMAT('$ARE WE DONE? ')
                END
```

```
FORTRAN IV-PLUS V02-51E          14:47:23    02-DEC-80          PAGE 10
OMEGA6.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                ATTRIBUTES

  1      $CODE1   001744    498          RW,I,CON,LCL
  2      $PDATA   000004      2          RW,D,CON,LCL
  3      $IDATA   000714    230          RW,D,CON,LCL
  4      $VARS    000036     15          RW,D,CON,LCL
  5      $TEMPS   000012      5          RW,D,CON,LCL
  6      .$$$$.   026060   5656          RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 SOURCE       1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 I      I*2   4-000024    IC     I*2   4-000030    ICNT   I*2   6-026056    ISCNT  I*2   6-026050    ISHOT  I*2   6-026052
 J      I*2   4-000032    JSHOT  I*2   6-026054    K      I*2   4-000034    L      I*2   4-000026

ARRAYS

 NAME   TYPE  ADDRESS       SIZE          DIMENSIONS

 IAUX   I*2   6-000000  000150    52      (52)
 IREP   I*2   6-017410  006440  1680      (12,140)
 ISFILE I*2   4-000000  000024    10      (10)
 REP    R*4   6-000150  017240  3920      (14,140)

LABELS

 LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS

 10       1-000014        20       1-000150        30       1-000200        40          **           50       1-000660
 60       1-001176        70          **           80       1-001304        90          **           100         **
 110      1-001606        120      1-001634        1000'    3-000000        1010'    3-000066        1020'    3-000072
 1030'    3-000126        1040'    3-000164        1050'    3-000276        1060'    3-000304        1070'    3-000326
 1080'    3-000472        1090'    3-000614

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE    OPEN$

TOTAL SPACE ALLOCATED = 031014  6406

SYO:[101,1]OMEGA6,SYO:[101,1]OMEGA6/-SP=SYO:[101,1]OMEGA6
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B(d;1) Omega-7 Lidar Data Output Program for Tabular Data and Graphic Plots (FORTRAN-4+), Average Form

B(d;2) Omega-8 Lidar Data Output Program for Tabular Data and Graphic Plots (FORTRAN-4+), Aggregate Form

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FORTRAN IV-PLUS V02-51E          10:49:27    04-FEB-81           PAGE 1
OMEGA7.FTN       /TR:BLOCKS/WR

0001                  PROGRAM OMEGA7
              C
              C       THIS PROGRAM IS USED TO GENERATE REPORTS AND PLOTS OF LIDAR
              C       OPACITY DATA GENERATED BY OMEGA1.
              C
0002                  COMMON REP(14,360),IREP(12,360),ISCNT,ISHOT,ICNT
0003                  DIMENSION IBTIM(2),IETIM(2),TITLE(25),IPTITL(26),IPFILE(10)
0004                  DIMENSION ISCR(20),IWTIM(4),ISTIM(2),INUM(3),SCR(20)
0005                  ISCNT=1           !SOURCE FILE COUNTER
0006                  IPCNT=1           !VECTOR FILE COUNTER
0007                  AVE=0.0           !AVERAGING INTERVAL
              C
              C       DX AND DY ARE THE PLOTTING INCREMENTS FOR DRAWING THE X'S AND ERROR
              C       BARS ON THE PLOT.
              C
0008                  DX=0.0333333
0009                  DY=0.0277778
              C
              C       IN THIS PROGRAM THE X DIRECTION IS DEFINED AS THE DIRECTION FROM
              C       LEFT TO RIGHT AS THE PRINTER IS VIEWED FROM THE FRONT.  THE PLOTTER
              C       SOFTWARE DEFINES THIS AS THE Y DIRECTION.  THE Y DIRECTION IS DEFINED
              C       AS THE DIRECTION FROM BOTTOM TO TOP AS THE PLOTTER IS VIEWED FROM THE
              C       FRONT.  THE PLOTTER DEFINES THIS AS THE -X DIRECTION.
              C
0010                  WRITE(5,1000)
              C
              C       GET THE FIRST SOURCE FILE
              C
0011                  CALL SOURCE
0012                  JCNT=1            !INPUT ARRAY INDEX
              C
              C       IF THERE ARE NO DATA IN THE INPUT ARRAY, CALL EXIT. WE ARE DONE.
              C
0013                  IF(ICNT.EQ.0)CALL EXIT
              C
              C       ENTER THE REPORT START TIME AND STOP TIME IN HOURS AND MINUTES
              C
0014                  WRITE(5,1010)
0015                  READ(5,*)IBTIM
0016                  WRITE(5,1020)
0017                  READ(5,*)IETIM
              C
              C       CONVERT STOP TIME TO MINUTES
              C
0018                  ETIM=60.0*IETIM(1)+IETIM(2)
0019                  WRITE(5,1030)    !IS A RUNNING AVERAGE INCLUDED?
0020                  READ(5,1040)IC
0021                  IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
              C
              C       YES, GET THE AVERAGING INTERVAL.
              C
0022                  WRITE(5,1050)
0023                  READ(5,*)AVE
              C
              C       GET VIOLATION STANDARDS FOR AVERAGE AND SINGLE EVENT
              C
```

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FORTRAN IV-PLUS V02-51E          10:49:27    04-FEB-81            PAGE 2
OMEGA7.FTN        /TR:BLOCKS/WR

0024      10      WRITE(5,1060)
0025              READ(5,*)VAVE,VSIN
0026              WRITE(5,1070)
          C
          C       GET THE REPORT TITLE. (100 CHARACTERS)
          C
0027              READ(5,1080)TITLE
          C
          C       GET THE PLOT TITLE. (50 CHARACTERS)
          C
0028              WRITE(5,1090)
0029              READ(5,1100)NCHR,IPTITL
0030              IPTITL(26)=0
0031              LINE=1            !REPORT LINE COUNTER. (50 LINES PER PAGE)
          C
          C       GET THE SPECIFICATION FOR THE NEXT PLOT FILE. (VECTOR FILE)
          C
0032      20      WRITE(5,1110)IPCNT
0033              READ(5,1040)IPFILE
0034              IPFILE(10)=0
0035              CALL NEWDEV(,IPFILE,0)  !NAME THE VECTOR AND PLOT FILES
          C
          C       INITIALIZE THE PLOTTING SOFTWARE.  (PLOTTING DIMENSIONS ARE SPECIFIED
          C       IN INCHES)
          C
0036              CALL PLOTST(,'IN',0)
          C
          C       DEFINE THE ORIGIN OF THE PLOT
          C
0037              CALL PLOT(7.0,1.9,-3)
          C
          C       DRAW THE BOTTOM AXIS OF THE PLOT
          C
0038              DO 30 I=1,20
0039              X=.5*I
0040              CALL PLOT(0.0,X,2)
0041              CALL PLOT(-0.0833333,X,2)
0042              CALL PLOT(0.0,X,3)
0043      30      CONTINUE
          C
          C       DRAW THE RIGHT SIDE AXIS OF THE PLOT
          C
0044              DO 40 I=1,11
0045              Y=0.416667*I
0046              CALL PLOT(-Y,10.0,2)
0047              CALL PLOT(-Y,9.91667,2)
0048              CALL PLOT(-Y,10.0,3)
0049      40      CONTINUE
          C
          C       DRAW THE TOP AXIS OF THE PLOT
          C
0050              DO 50 I=19,0,-1
0051              X=.5*I
0052              CALL PLOT(-4.58333,X,2)
0053              CALL PLOT(-4.5,X,2)
0054              CALL PLOT(-4.58333,X,3)
```

```
50      CONTINUE
C
C       DRAW THE LEFT AXIS OF THE PLOT
C
        DO 60   I=10,0,-1
        Y=.416667*I
        CALL PLOT(-Y,0.0,2)
        CALL PLOT(-Y,0.0833333,2)
        CALL PLOT(-Y,0.0,3)
60      CONTINUE
C
C       LABEL THE TICK MARKS ON THE BOTTOM AXIS IN HOURS:MINUTES.
C
        ISTIM(1)=IBTIM(1)
        ISTIM(2)=IBTIM(2)
        Y=-.208333
        DO 70 I=0,10,2
        ENCODE(8,1120,ISCR)ISTIM
        DECODE(8,1040,ISCR)IWTIM
        IWTIM(4)=0
        X=1.0*I-.25
        CALL SYMBOL(-Y,X,.116667,IWTIM,90.0,5)
        ISTIM(2)=ISTIM(2)+2
        IF(ISTIM(2).LT.60)GOTO 70
        ISTIM(2)=ISTIM(2)-60
        ISTIM(1)=ISTIM(1)+1
        IF(ISTIM(1).LT.24)GOTO 70
        ISTIM(1)=0
70      CONTINUE
C
C       WRITE THE CAPTION ON THE BOTTOM AXIS
C
        Y=-.541667
C
C       THE FOLLOWING TWO STATEMENTS ARE CHANGED FOR DIFFERENT TIME ZONES
C
        X=3.9
        CALL SYMBOL(-Y,X,.194444,'CENTRAL TIME',90.0,12)
C
C       WRITE THE PLOT TITLE AT THE BOTTOM OF THE PLOT
C
        Y=-1.04167
        X=5.0-0.1*NCHR
        CALL SYMBOL(-Y,X,.194444,IPTITL,90.0,NCHR)
C
C       LABEL THE TICK MARKS ON THE VERTICAL AXIS. (OPACITY -10% TO 100%)
C
        X=-.4
        DO 80 I=0,11
        Y=I*0.416667-.05
        NUM=10*I-10
        ENCODE(6,1130,ISCR)NUM
        DECODE(6,1040,ISCR)INUM
        INUM(3)=0
        CALL SYMBOL(-Y,X,.116667,INUM,90.0,3)
80      CONTINUE
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FORTRAN IV-PLUS V02-51E        10:49:27    04-FEB-81          PAGE 4
OMEGA7.FTN        /TR:BLOCKS/WR

             C
             C         WRITE THE CAPTION ON THE LEFT VERTICAL AXIS
             C
0093                   X=-.45
0094                   Y=1.54167
0095                   CALL SYMBOL(-Y,X,.233333,'% OPACITY',180.0,9)
             C
             C         WRITE THE DATE THE DATA WAS TAKEN ABOVE THE PLOT ON THE LEFT HAND SIDE
             C
0096                   ENCODE(14,1220,ISCR)(IREP(I,JCNT),I=1,3)
0097                   ISCR(8)=8
0098                   CALL SYMBOL(-4.69444,0.0,.116667,ISCR,90.0,14)
             C
             C         WRITE THE LEGEND FOR THE SINGLE EVENT OPACITY STANDARD ABOVE THE PLOT
             C         ON THE RIGHT HAND SIDE
             C
             C         CALL SYMBOL(-4.90278,5.8,.116667,'SINGLE EVENT OPACITY STANDARD'
             C         1,90.0,29)
             C         CALL PLOT(-4.95833,9.3,3)
             C         CALL PLOT(-4.95833,9.55,2)
             C         CALL PLOT(-4.95833,9.60,3)
             C         CALL PLOT(-4.95833,9.70,2)
             C         CALL PLOT(-4.95833,9.75,3)
             C         CALL PLOT(-4.95833,10.0,2)
0099                   X=6.38333
             C
             C         WRITE THE LEGEND FOR AVERAGE OPACITY STANDARD ABOVE THE PLOT ON THE
             C         RIGHT HAND SIDE BELOW THE LEGEND FOR SINGLE EVENT STANDARD
             C
0100                   CALL SYMBOL(-4.69444,X,.116667,'AVERAGE OPACITY STANDARD',90.0
                       1,24)
0101                   CALL PLOT(-4.75,9.3,3)
0102                   CALL PLOT(-4.75,9.4,2)
0103                   CALL PLOT(-4.75,9.45,3)
0104                   CALL PLOT(-4.75,9.55,2)
0105                   CALL PLOT(-4.75,9.6,3)
0106                   CALL PLOT(-4.75,9.7,2)
0107                   CALL PLOT(-4.75,9.75,3)
0108                   CALL PLOT(-4.75,9.85,2)
0109                   CALL PLOT(-4.75,9.9,3)
0110                   CALL PLOT(-4.75,10.0,2)
             C
             C         WRITE THE LEGEND FOR CALCULATED OPACITY PLUS OR MINUS STANDARD DEVIATION
             C         ABOVE THE PLOT IN THE CENTER
             C
0111                   Y=4.86111
0112                   X=2.0
0113                   CALL PLOT(DY-Y,X-DX,3)
0114                   CALL PLOT(-Y-DY,X+DX,2)
0115                   CALL PLOT(-Y-DY,X-DX,3)
0116                   CALL PLOT(DY-Y,X+DX,2)
0117                   CALL PLOT(-4.70833,X-DX,3)
0118                   CALL PLOT(-4.70833,X+DX,2)
0119                   CALL PLOT(-4.70833,X,3)
0120                   CALL PLOT(-5.01389,X,2)
0121                   CALL PLOT(-5.01389,X-DX,2)
```

```
              CALL PLOT(-5.01389,X+DX,2)
              X=2.15
              CALL SYMBOL(-4.90278,X,.116667,'CALCULATED OPACITY PLUS OR'
              1,90.0,26)
              CALL SYMBOL(-4.69444,X,.116667,'MINUS ONE STANDARD DEVIATION'
              1,90.0,28)
              Y=.416667
C
C             REDEFINE THE ORIGIN FOR PLOTTING
C
              CALL PLOT(-Y,0.0,-3)
C
C             DRAW A LONG DASHED LINE AT THE 0% OPACITY LEVEL
C
              DO 90 I=1,75
              IP=2
              IF(MOD(I,4).EQ.0)IP=3
              X=I*.133333
              CALL PLOT(0.0,X,IP)
   90         CONTINUE
C
C             DRAW A SHORT DASHED LINE AT THE AVERAGE OPACITY STANDARD VALUE
C
              Y=VAVE*.0416667
              CALL PLOT(-Y,0.0,3)
              DO 100 I=1,200
              IP=2
              IF(MOD(I,3).EQ.0)IP=3
              X=I*.050
              CALL PLOT(-Y,X,IP)
  100         CONTINUE
C
C             DRAW A LONG-SHORT DASHED LINE AT THE SINGLE EVENT OPACITY STANDARD
C             VALUE
C
              Y=VSIN*.0416667
              CALL PLOT(-Y,0.0,3)
              DO 110 I=1,200
              IP=2
              IF(MOD(I+3,12).EQ.0.OR.MOD(I,12).EQ.0)IP=3
              X=I*.0500
              CALL PLOT(-Y,X,IP)
  110         CONTINUE
C
C             BEGINNING TIME FOR THE CURRENT PLOT IN MINUTES
C
              BTIM=IBTIM(1)*60.0+IBTIM(2)
              TTT=ETIM        !REPORT END TIME
C
C             IF THE REPORT INTERVAL INCLUDES MIDNIGHT, ADD 1440 TO TTT, THE
C             END OF THE REPORT INTERVAL
C
              IF(TTT.LT.BTIM)TTT=TTT+1440.0
              PETIM=BTIM+10.0          !END OF THE CURRENT PLOT
C
C             IF THE END OF THE REPORT INTERVAL OCCURS BEFORE THE END OF THE CURRENT
```

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FORTRAN IV-PLUS V02-51E          10:49:27     04-FEB-81           PAGE 6
OMEGA7.FTN          /TR:BLOCKS/WR

            C          PLOT, SET PETIM EQUAL TO TTT
            C
0154                   IF(PETIM.GE.TTT)PETIM=TTT
            C
            C          PTIM IS THE TIME OF THE CURRENT SHOT IN MINUTES
            C
0155        120        PTIM=60.0*IREP(4,JCNT)+IREP(5,JCNT)+IREP(6,JCNT)/60.0
            C
            C          MIDNIGHT CORRECTION
            C
0156                   IF(PETIM.GT.1440.0.AND.PTIM.LE.PETIM-1440.0)PTIM=PTIM+1440.0
            C
            C          IF THE POINT IS AT THE END OR OUTSIDE OF THE CURRENT PLOT INTERVAL.
            C          CLOSE THE PLOT AND OPEN ANOTHER ONE IF THERE IS STILL MORE DATA
            C          TO BE PLOTTED.  (GO TO 170)
            C
0157                   IF(PTIM.GE.PETIM)GOTO 170
            C
            C          IF THE POINT OCCURS BEFORE THE CURRENT PLOT INTERVAL, GO GET THE NEXT
            C          POINT
            C
0158                   IF(PTIM.LT.BTIM)GOTO 160
            C
            C          IF 'SO' FOR THIS POINT IS TOO BIG, GET THE NEXT POINT
            C
0159        130        IF(REP(11,JCNT).GE.8.5)GOTO 160
            C
            C          GET THE X AND Y COORDINATES FOR PLOTTING
            C
0160                   X=PTIM-BTIM
0161                   Y=REP(10,JCNT)*.0416667
            C
            C          FORCE OPACITIES LESS THAN ZERO TO ZERO
            C
0162                   IF(Y.LT.0.0)Y=0.0
            C
            C          CONVERT 'SO' TO PLOTTING COORDINATES
            C
0163                   DELY=REP(11,JCNT)*.0416667
            C
            C          PLOT THE OPACITY PLUS OR MINUS STANDARD DEVIATION WITH AN 'X' MARKING
            C          THE OPACITY AND AN ERROR BAR INDICATING THE STANDARD DEVIATION.
            C
0164                   CALL PLOT(DY-Y,X-DX,3)
0165                   CALL PLOT(-Y-DY,X+DX,2)
0166                   CALL PLOT(-Y-DY,X-DX,3)
0167                   CALL PLOT(DY-Y,X+DX,2)
0168                   CALL PLOT(DELY-Y,X-DX,3)
0169                   CALL PLOT(DELY-Y,X+DX,2)
0170                   CALL PLOT(DELY-Y,X,3)
0171                   CALL PLOT(-Y-DELY,X,2)
0172                   CALL PLOT(-Y-DELY,X-DX,2)
0173                   CALL PLOT(-Y-DELY,X+DX,2)
0174                   IF(LINE.GT.1)GOTO 140
            C
            C          THIS IS THE FIRST LINE ON THE REPORT PAGE.  WRITE THE HEADR FIRST
```

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FORTRAN IV-PLUS V02-51E          10:49:27     04-FEB-81            PAGE 7
OMEGA7.FTN          /TR:BLOCKS/WR

      C
                WRITE(6,1140)
                WRITE(6,1150)TITLE
                WRITE(6,1160)
      C
      C         PRINT THE INFORMATION FROM THIS SHOT IN THE REPORT
      C
      140       A=0.0
                B=0.0
                M1=0
                M2=0
                C=REP(10,JCNT)   !OPACITY
                D=REP(11,JCNT)   !SO
                IF(C.LT.0.0)C=0.0
                IF(REP(14,JCNT)+.33.LT.AVE)GOTO 150
                A=REP(12,JCNT)   !AVERAGE OPACITY
                B=REP(13,JCNT)   !AVERAGE SO
                IF(A.LT.0.0)A=0.0
      C
      C         M1 IS THE NUMBER OF SHOTS DISCARDED IN THE CURRENT RUNNING AVERAGE
      C         BECAUSE SO WAS TOO BIG
      C
                M1=IREP(12,JCNT)-IREP(11,JCNT)
                M2=IREP(12,JCNT)          !NUMBER OF SO'S IN THE CURRENT RUNNING AVERAGE
      C
      C         CHANGE THE OPACITY AND SO TOO INTEGERS
      C
      150       ENCODE(15,1170,SCR)A,B
                DECODE(15,1180,SCR)IA,IB
                ENCODE(15,1170,SCR)C,D
                DECODE(15,1180,SCR)IC,ID
                WRITE(6,1190)(IREP(M,JCNT),M=1,6),IC,ID,IA,IB,M1,M2
      C
      C         INDICATE AVERAGE OR SINGLE EVENT VIOLATIONS WITH ASTERISKS
      C
                IF(REP(10,JCNT)-2.*REP(11,JCNT).GE.VSIN)WRITE(6,1200)
                IF(A-2.*REP(13,JCNT).GE.VAVE)WRITE(6,1210)
      C
      C         INCREMENT THE LINE COUNTER, 50 LINES PER PAGE
      C
                LINE=LINE+1
                IF(LINE.GT.50)LINE=1
      C
      C         INCREMENT THE INPUT ARRAY COUNTER.  IF THERE IS NO MORE DATA IN THE
      C         INPUT ARRAY, READ ANOTHER FILE IN.
      C
      160       JCNT=JCNT+1
                IF(JCNT.LE.ICNT)GOTO 120
                CALL SOURCE
                JCNT=1
      C
      C         IF ANOTHER INPUT FILE WAS NOT SPECIFIED WE ARE DONE.
      C
                IF(ICNT.EQ.0)GOTO 190
                GOTO 120
      170       IF(PTIM.GT.PETIM)GOTO 180
```

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FORTRAN IV-PLUS V02-51E        10:49:27    04-FEB-81           PAGE 8
OMEGA7.FTN        /TR:BLOCKS/WR

            C
            C        IF THIS POINT IS AT THE END OF THE CURRENT PLOT AND AT THE END OF
            C        THE REPORT INTERVAL, PUT IT ON THIS PLOT.
            C
   0207              IF(PTIM.EQ.TTT)GOTO 130
            C
            C        CURRENT PLOT IS FINISHED.  CLOSE IT OUT.
            C
   0208     180      CALL PLOTND
            C
            C        INCREMENT BEGINNING TIME FOR THE NEXT PLOT
            C
   0209              IBTIM(2)=IBTIM(2)+10
   0210              IF(IBTIM(2).LT.60)GOTO 185
   0211              IBTIM(2)=IBTIM(2)-60
   0212              IBTIM(1)=IBTIM(1)+1
   0213              IF(IBTIM(1).EQ.24)IBTIM(1)=0
   0214     185      TT=60.0*IBTIM(1)+IBTIM(2)
   0215              IF(TT.GE.TTT)GOTO 190
            C
            C        INCREMENT THE PLOT FILE COUNTER AND GET THE NEXT PLOT FILE SPECIFICATION
            C        (VECTOR FILE)
            C
   0216     188      IPCNT=IPCNT+1
   0217              CALL WAIT(3,2,IWSTAT)    !WAIT FOR PLOTND TO CLOSE THE OLD VECTOR FILE
   0218              GOTO 20          !GET NEXT PLOT FILE
            C
            C        END OF PROGRAM, CLOSE THE CURRENT PLOT FILE AND EXIT
            C
   0219     190      CALL PLOTND
   0220              CALL WAIT(3,2,IWSTAT)
   0221              CALL EXIT
            C
            C        FORMAT STATEMENTS
            C
   0222     1000     FORMAT(' THIS PROGRAM MAKES TABLES AND PLOTS OF LIDAR OPACITY',
                     1' DATA GENERATED BY OMEGA1.'//)
   0223     1010     FORMAT('$ENTER REPORT START TIME: HOURS, MINUTES ')
   0224     1020     FORMAT('$ENTER REPORT STOP TIME: HOURS, MINUTES ')
   0225     1030     FORMAT('$WILL DATA BE AVERAGED? ')
   0226     1040     FORMAT(20A2)
   0227     1050     FORMAT('$ENTER AVERAGING INTERVAL IN MINUTES: ')
   0228     1060     FORMAT('$ENTER VIOLATION VALUES FOR AVERAGE, SINGLE EVENT: ')
   0229     1070     FORMAT(' ENTER TABLE TITLE.  100 CHARACTERS MAXIMUM.')
   0230     1080     FORMAT(20A4/13A4)
   0231     1090     FORMAT(' ENTER PLOT TITLE.  50 CHARACTERS MAXIMUM.')
   0232     1100     FORMAT(Q,26A2)
   0233     1110     FORMAT('$ENTER FILE SPECIFICATION FOR PLOT FILE NUMBER',I3,1X)
   0234     1120     FORMAT(I2,':',I2,3X)
   0235     1130     FORMAT(I3,3X)
   0236     1140     FORMAT(1H1,44X,'UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'
                     1/46X,'NATIONAL ENFORCEMENT INVESTIGATIONS CENTER'
                     2/56X,'DENVER, COLORADO 80225'//)
   0237     1150     FORMAT(16X,25A4)
   0238     1160     FORMAT(18X,'DATE',6X,'TIME    OPACITY   SO  VIOLATION',
                     1'  AVERAGE OPACITY  AVERAGE SO  VIOLATION  NUMBER DISCARDED'/)
```

```
1170   FORMAT(1X,F7.0,F7.0)
1180   FORMAT(I7,1X,I6)
1190   FORMAT(16X,I2,'/',I2,'/',I2,I4,':',I2,':',I2,3X,I4,4X,I3
      1,18X,I4,11X,I3,20X,I3,' OF',I4)
1200   FORMAT(1H+,T53,'****')
1210   FORMAT(1H+,T93,'****')
1220   FORMAT('DATE:  ',I2,'/',I2,'/',I2)
       END
```

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FORTRAN IV-PLUS V02-51E              10:49:27     04-FEB-81          PAGE 10
OMEGA7.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                    ATTRIBUTES

   1     $CODE1   006702  1761               RW,I,CON,LCL
   2     $PDATA   000524   170               RW,D,CON,LCL
   3     $IDATA   002452   661               RW,D,CON,LCL
   4     $VARS    000644   210               RW,D,CON,LCL
   5     $TEMPS   000020     8               RW,D,CON,LCL
   6     .$$$$.   070206 14403               RW,D,OVR,GBL

VARIABLES

NAME    TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

A       R*4   4-000602    AVE    R*4   4-000500    B      R*4   4-000606    BTIM   R*4   4-000556    C      R*4   4-000616
D       R*4   4-000622    DELY   R*4   4-000576    DX     R*4   4-000504    DY     R*4   4-000510    ETIM   R*4   4-000516
I       I*2   4-000540    IA     I*2   4-000626    IB     I*2   4-000630    IC     I*2   4-000522    ICNT   I*2   6-070204
ID      I*2   4-000632    IP     I*2   4-000554    IPCNT  I*2   4-000476    ISCNT  I*2   6-070200    ISHOT  I*2   6-070202
IWSTAT  I*2   4-000642    JCNT   I*2   4-000514    LINE   I*2   4-000536    M      I*2   4-000634    M1     I*2   4-000612
M2      I*2   4-000614    NCHR   I*2   4-000534    NUM    I*2   4-000552    PETIM  R*4   4-000566    PTIM   R*4   4-000572
TT      R*4   4-000636    TTT    R*4   4-000562    VAVE   R*4   4-000524    VSIN   R*4   4-000530    X      R*4   4-000542
Y       R*4   4-000546

ARRAYS

NAME    TYPE  ADDRESS        SIZE          DIMENSIONS

IBTIM   I*2   4-000000  000004      2      (2)
IETIM   I*2   4-000004  000004      2      (2)
INUM    I*2   4-000350  000006      3      (3)
IPFILE  I*2   4-000240  000024     10      (10)
IPTITL  I*2   4-000154  000064     26      (26)
IREP    I*2   6-047300  020700   4320      (12,360)
ISCR    I*2   4-000264  000050     20      (20)
ISTIM   I*2   4-000344  000004      2      (2)
IWTIM   I*2   4-000334  000010      4      (4)
REP     R*4   6-000000  047300  10080      (14,360)
SCR     R*4   4-000356  000120     40      (20)
TITLE   R*4   4-000010  000144     50      (25)

LABELS

LABEL   ADDRESS       LABEL   ADDRESS       LABEL   ADDRESS       LABEL   ADDRESS       LABEL   ADDRESS

10      1-000436      20      1-000662      30         **         40         **         50         **
60         **         70      1-001752      80         **         90         **         100        **
110        **         120     1-004246      130     1-004420      140     1-005376      150     1-005574
160     1-006346      170     1-006424      180     1-006470      185     1-006552      188        **
190     1-006640      1000'   3-000000      1010'   3-000126      1020'   3-000202      1030'   3-000256
1040'   3-000312      1050'   3-000316      1060'   3-000370      1070'   3-000456      1080'   3-000536
1090'   3-000546      1100'   3-000624      1110'   3-000632      1120'   3-000716      1130'   3-000730
1140'   3-000736      1150'   3-001136      1160'   3-001144      1170'   3-001316      1180'   3-001326
```

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FORTRAN IV-PLUS V02-51E          10:49:27     04-FEB-81            PAGE 11
OMEGA7.FTN         /TR:BLOCKS/WR

 1190'   3-001334         1200'   3-001416         1210'   3-001432         1220'   3-001446

FUNCTIONS AND SUBROUTINES REFERENCED

 EXIT     NEWDEV  PLOT     PLOTND  PLOTST  SOURCE  SYMBOL  WAIT

TOTAL SPACE ALLOCATED = 103172 17213
```

```
0001                    SUBROUTINE SOURCE
                C
                C       THIS SUBROUTINE READS DATA FROM A DESIGNATED DISC FILE
                C       INTO REP AND IREP
                C
0002                    COMMON REP(14,360),IREP(12,360),ISCNT,ISHOT,ICNT
0003                    DIMENSION ISFILE(10),IAUX(52)
                C
                C       GET THE FILE SPECIFICATION FOR INPUT FILE NUMBER ISCNT
                C
0004            10      WRITE(5,1000)ISCNT
0005                    READ(5,1010)ISFILE
0006                    IF(ISFILE(2).EQ.'  ')GOTO 120
0007                    ISFILE(10)=0
0008                    CALL CLOSE(3)
0009                    OPEN(UNIT=3,NAME=ISFILE,TYPE='OLD',READONLY,ERR=20
                        1,DISPOSE='SAVE')
0010                    GOTO 30
                C
                C       HERE IF ERROR OPENING DISC FILE
                C
0011            20      WRITE(5,1020)
0012                    GOTO 10
                C
                C       READ HEADER INFORMATION
                C
0013            30      READ(3,1030)IAUX
                C
                C       DISPLAY THE HEADER INFORMATION ON THE TERMINAL
                C
0014                    WRITE(5,1040)IAUX(7),(IAUX(I),I=1,6),IAUX(8),IAUX(9)
0015                    WRITE(5,1050)(IAUX(I),I=21,52)
                C
                C       READ DATA INTO THE INPUT ARRAYS
                C
0016                    DO 40 I=1,360
0017                    READ(3,1060,END=50)(IREP(L,I),L=1,12),(REP(L,I),L=1,14)
0018            40      CONTINUE
0019            50      CALL CLOSE(3)
0020                    ICNT=I-1          !NUMBER OF SHOTS IN THE INPUT FILE
                C
                C       TELL THE OPERATOR WHICH SHOTS ARE INCLUDED IN THIS FILE AND
                C       VERIFY THAT THIS IS THE CORRECT FILE.
                C
0021                    WRITE(5,1070)ISHOT,IREP(7,1),IREP(7,ICNT)
0022                    READ(5,1010)IC
0023                    IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
0024                    IF(ISCNT.EQ.1)GOTO 60
                C
                C       CHECK TO SEE THAT THIS FILE INCLUDES THE NEXT SHOT.  IF IT DOES NOT,
                C       TELL THE OPERATOR AND VERIFY THAT THIS IS THE CORRECT FILE.
                C
0025                    IF(IREP(7,1).LE.ISHOT+1.AND.IREP(7,ICNT).GE.ISHOT+1)GOTO 60
0026                    WRITE(5,1080)
0027                    READ(5,1010)IC
0028                    IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
```

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FORTRAN IV-PLUS V02-51E        10:49:49    04-FEB-81          PAGE 13
OMEGA7.FTN          /TR:BLOCKS/WR

0029     60       ISCNT=ISCNT+1
         C
         C        IF THIS IS THE FIRST FILE, KEEP ALL THE DATA.
         C
0030              IF(ISCNT.EQ.2)GOTO 110
0031              IF(ISHOT.LT.IREP(7,1))GOTO 110
         C
         C        IF THIS IS NOT THE FIRST FILE, KEEP ONLY THE DATA WHICH HAS NOT
         C        ALREADY BEEN PLOTTED.
         C
0032              DO 70 I=1,ICNT
0033              IF(ISHOT.EQ.IREP(7,I))GOTO 80
0034     70       CONTINUE
0035              I=I-1
0036     80       DO 100 J=1,ICNT-I
0037              DO 90 K=1,12
0038              IREP(K,J)=IREP(K,J+I)
0039              REP(K,J)=REP(K,J+I)
0040     90       CONTINUE
0041              REP(13,J)=REP(13,J+I)
0042              REP(14,J)=REP(14,J+I)
0043     100      CONTINUE
0044              ICNT=ICNT-I
0045     110      ISHOT=IREP(7,ICNT)
0046              RETURN
         C
         C        NO INPUT FILE WAS SPECIFIED.  VERIFY THAT NO NEW FILE IS DESIRED,
         C        AND RETURN WITH THE FILE SIZE SET TO ZERO.
         C
0047     120      WRITE(5,1090)
0048              READ(5,1010)IC
0049              IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
0050              ICNT=0
0051              RETURN
         C
         C        FORMAT STATEMENTS
         C
0052     1000     FORMAT(' ENTER FILE SPECIFICATION FOR SOURCE FILE NUMBER',I3,1X)
0053     1010     FORMAT(20A2)
0054     1020     FORMAT(' ERROR OPENING DISC FILE!')
0055     1030     FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
0056     1040     FORMAT(/' FILE',I5,I4,'/',I2,'/',I2,I4,':',I2,':',I2,2X,
                  1'REF. FILE',I5,2X,'GATE CALIBRATION FILE',I5/)
C057     1050     FORMAT(1X,32A2/)
0058     1060     FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
0059     1070     FORMAT(' LAST SHOT WAS:',I5,'  THIS FILE STARTS AT SHOT',I5,
                  1' AND RUNS TO SHOT',I5/'$IS THIS THE RIGHT FILE? ')
0060     1080     FORMAT('$THIS FILE DOES NOT INCLUDE THE NEXT SHOT.',
                  1'  ARE YOU SURE IT''S THE RIGHT ONE? ')
0061     1090     FORMAT('$ARE WE DONE? ')
0062              END
```

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FORTRAN IV-PLUS V02-51E        10:49:49    04-FEB-81          PAGE 14
OMEGA7.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                ATTRIBUTES

  1      $CODE1  001744    498           RW,I,CON,LCL
  2      $PDATA  000004      2           RW,D,CON,LCL
  3      $IDATA  000714    230           RW,D,CON,LCL
  4      $VARS   000206     67           RW,D,CON,LCL
  5      $TEMPS  000012      5           RW,D,CON,LCL
  6      .$$$$.  070206 14403            RW,D,OVR,GBL

ENTRY POINTS

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 SOURCE       1-000000

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 I      I*2   4-000174    IC     I*2   4-000200    ICNT   I*2   6-070204    ISCNT  I*2   6-070200    ISHOT  I*2   6-070202
 J      I*2   4-000202    K      I*2   4-000204    L      I*2   4-000176

ARRAYS

 NAME   TYPE  ADDRESS        SIZE        DIMENSIONS

 IAUX   I*2   4-000024  000150    52     (52)
 IREP   I*2   6-047300  020700  4320     (12,360)
 ISFILE I*2   4-000000  000024    10     (10)
 REP    R*4   6-000000  047300 10080     (14,360)

LABELS

 LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS          LABEL   ADDRESS

 10      1-000014         20      1-000150         30      1-000200         40         **            50      1-000660
 60      1-001176         70         **            80      1-001304         90         **            100        **
 110     1-001606         120     1-001634         1000'   3-000000         1010'   3-000066         1020'   3-000072
 1030'   3-000126         1040'   3-000164         1050'   3-000276         1060'   3-000304         1070'   3-000326
 1080'   3-000472         1090'   3-000614

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   OPEN$

TOTAL SPACE ALLOCATED = 073312 15205

SYO:[101,1]OMEGA7,SYO:[101,1]OMEGA7/-SP=SYO:[101,1]OMEGA7
```

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FORTRAN IV-PLUS V02-51E          14:40:08    23-MAR-81          PAGE 1
OMEGA8.FTN       /TR:BLOCKS/WR

0001                 PROGRAM OMEGA8
           C
           C         THIS PROGRAM IS USED TO GENERATE REPORTS AND PLOTS OF LIDAR
           C         OPACITY DATA GENERATED BY OMEGA5.   AGGREGATE VERSION
           C
0002                 COMMON REP(14,360),IREP(12,360),ISCNT,ISHOT,ICNT
0003                 DIMENSION IBTIM(2),IETIM(2),TITLE(25),IPTITL(26),IPFILE(10)
0004                 DIMENSION ISCR(20),IWTIM(4),ISTIM(2),INUM(3),SCR(20)
0005                 BYTE AFLG
0006                 ISCNT=1           !SOURCE FILE COUNTER
0007                 IPCNT=1           !VECTOR FILE COUNTER
0008                 AVE=0.0           !AVERAGING INTERVAL
           C
           C         DX AND DY ARE THE PLOTTING INCREMENTS FOR DRAWING THE X'S AND ERROR
           C         BARS ON THE PLOT.
           C
0009                 DX=0.0333333
0010                 DY=0.0277778
           C
           C         IN THIS PROGRAM THE X DIRECTION IS DEFINED AS THE DIRECTION FROM
           C         LEFT TO RIGHT AS THE PRINTER IS VIEWED FROM THE FRONT.  THE PLOTTER
           C         SOFTWARE DEFINES THIS AS THE Y DIRECTION.  THE Y DIRECTION IS DEFINED
           C         AS THE DIRECTION FROM BOTTOM TO TOP AS THE PLOTTER IS VIEWED FROM THE
           C         FRONT.  THE PLOTTER DEFINES THIS AS THE -X DIRECTION.
           C
0011                 WRITE(5,1000)
           C
           C         GET THE FIRST SOURCE FILE
           C
0012                 CALL SOURCE
0013                 JCNT=1            !INPUT ARRAY INDEX
           C
           C         IF THERE ARE NO DATA IN THE INPUT ARRAY, CALL EXIT.  WE ARE DONE.
           C
0014                 IF(ICNT.EQ.0)CALL EXIT
           C
           C         ENTER THE REPORT START TIME AND STOP TIME IN HOURS AND MINUTES
           C
0015                 WRITE(5,1010)
0016                 READ(5,*)IBTIM
0017                 WRITE(5,1020)
0018                 READ(5,*)IETIM
           C
           C         CONVERT STOP TIME TO MINUTES
           C
0019                 ETIM=60.0*IETIM(1)+IETIM(2)
           C         WRITE(5,1030)    !IS A RUNNING AVERAGE INCLUDED?
           C         READ(5,1040)IC
           C         IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
           C
           C         YES, GET THE AVERAGING INTERVAL.
           C
0020                 WRITE(5,1050)
0021                 READ(5,*)AVE
           C
           C         GET VIOLATION STANDARDS FOR AVERAGE AND SINGLE EVENT
```

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FORTRAN IV-PLUS V02-51E         14:40:08    23-MAR-81           PAGE 2
OMEGA8.FTN       /TR:BLOCKS/WR

          C
0022      10      WRITE(5,1060)
0023              READ(5,*)VAVE,VSIN
0024              WRITE(5,1070)
          C
          C       GET THE REPORT TITLE, (100 CHARACTERS)
          C
0025              READ(5,1080)TITLE
          C
          C       GET THE PLOT TITLE, (50 CHARACTERS)
          C
0026              WRITE(5,1090)
0027              READ(5,1100)NCHR,IPTITL
0028              IPTITL(26)=0
0029              ATIM=0.0
0030              AETIM=0.0
0031              AFLG=.FALSE.
0032              ITOTAL=0
0033              IHISO=0
0034              IFLAG=0
0035              LINE=1            !REPORT LINE COUNTER, (50 LINES PER PAGE)
          C
          C       GET THE SPECIFICATION FOR THE NEXT PLOT FILE, (VECTOR FILE)
          C
0036      20      WRITE(5,1110)IPCNT
0037              READ(5,1040)IPFILE
0038              IPFILE(10)=0
0039              CALL NEWDEV(,IPFILE,0)  !NAME THE VECTOR AND PLOT FILES
          C
          C       INITIALIZE THE PLOTTING SOFTWARE.  (PLOTTING DIMENSIONS ARE SPECIFIED
          C       IN INCHES)
          C
0040              CALL PLOTST(,'IN',0)
          C
          C       DEFINE THE ORIGIN OF THE PLOT
          C
0041              CALL PLOT(7.0,1.9,-3)
          C
          C       DRAW THE BOTTOM AXIS OF THE PLOT
          C
0042              DO 30 I=1,20
0043              X=.5*I
0044              CALL PLOT(0.0,X,2)
0045              CALL PLOT(-0.0833333,X,2)
0046              CALL PLOT(0.0,X,3)
0047      30      CONTINUE
          C
          C       DRAW THE RIGHT SIDE AXIS OF THE PLOT
          C
0048              DO 40 I=1,11
0049              Y=0.416667*I
0050              CALL PLOT(-Y,10.0,2)
0051              CALL PLOT(-Y,9.91667,2)
0052              CALL PLOT(-Y,10.0,3)
0053      40      CONTINUE
          C
```

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FORTRAN IV-PLUS V02-51E          14:40:08     23-MAR-81            PAGE 3
OMEGA .FTN          /TR:BLOCKS/WR

              C         DRAW THE TOP AXIS OF THE PLOT
              C
0054                    DO 50 I=19,0,-1
0055                    X=.5*I
0056                    CALL PLOT(-4.58333,X,2)
0057                    CALL PLOT(-4.5,X,2)
0058                    CALL PLOT(-4.58333,X,3)
0059          50        CONTINUE
              C
              C         DRAW THE LEFT AXIS OF THE PLOT
              C
0060                    DO 60   I=10,0,-1
0061                    Y=.416667*I
0062                    CALL PLOT(-Y,0.0,2)
0063                    CALL PLOT(-Y,0.0833333,2)
0064                    CALL PLOT(-Y,0.0,3)
0065          60        CONTINUE
              C
              C         LABEL THE TICK MARKS ON THE BOTTOM AXIS IN HOURS:MINUTES.
              C
0066                    ISTIM(1)=IBTIM(1)
0067                    ISTIM(2)=IBTIM(2)
0068                    Y=-.208333
0069                    DO 70 I=0,10,2
0070                    ENCODE(8,1120,ISCR)ISTIM
0071                    DECODE(8,1040,ISCR)IWTIM
0072                    IWTIM(4)=0
0073                    X=1.0*I-.25
0074                    CALL SYMBOL(-Y,X,.116667,IWTIM,90.0,5)
0075                    ISTIM(2)=ISTIM(2)+2
0076                    IF(ISTIM(2).LT.60)GOTO 70
0077                    ISTIM(2)=ISTIM(2)-60
0078                    ISTIM(1)=ISTIM(1)+1
0079                    IF(ISTIM(1).LT.24)GOTO 70
0080                    ISTIM(1)=0
0081          70        CONTINUE
              C
              C         WRITE THE CAPTION ON THE BOTTOM AXIS
              C
0082                    Y=-.541667
              C
              C         THE FOLLOWING TWO STATEMENTS ARE CHANGED FOR DIFFERENT TIME ZONES
              C
0083                    X=3.9
0084                    CALL SYMBOL(-Y,X,.194444,'CENTRAL TIME',90.0,12)
              C
              C         WRITE THE PLOT TITLE AT THE BOTTOM OF THE PLOT
              C
0085                    Y=-1.04167
0086                    X=5.0-0.1*NCHR
0087                    CALL SYMBOL(-Y,X,.194444,IPTITL,90.0,NCHR)
              C
              C         LABEL THE TICK MARKS ON THE VERTICAL AXIS. (OPACITY -10% TO 100%)
              C
0088                    X=-.4
0089                    DO 80 I=0,11
```

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FORTRAN IV-PLUS V02-51E        14:40:08    23-MAR-81          PAGE 4
OMEGAB.FTN        /TR:BLOCKS/WR

0090                Y=I*0.416667-.05
0091                NUM=10*I-10
0092                ENCODE(6,1130,ISCR)NUM
0093                DECODE(6,1040,ISCR)INUM
0094                INUM(3)=0
0095                CALL SYMBOL(-Y,X,.116667,INUM,90.0,3)
0096        80      CONTINUE
            C
            C       WRITE THE CAPTION ON THE LEFT VERTICAL AXIS
            C
0097                X=-.45
0098                Y=1.54167
0099                CALL SYMBOL(-Y,X,.233333,'% OPACITY',180.0,9)
            C
            C       WRITE THE DATE THE DATA WAS TAKEN ABOVE THE PLOT ON THE LEFT HAND SIDE
            C
0100                ENCODE(14,1220,ISCR)(IREP(I,JCNT),I=1,3)
0101                ISCR(8)=8
0102                CALL SYMBOL(-4.69444,0.0,.116667,ISCR,90.0,14)
            C
            C       WRITE THE LEGEND FOR THE SINGLE EVENT OPACITY STANDARD ABOVE THE PLOT
            C       ON THE RIGHT HAND SIDE
            C
0103                CALL SYMBOL(-4.90278,5.8,.116667,'SINGLE EVENT OPACITY STANDARD'
                    1,90.0,29)
0104                CALL PLOT(-4.95833,9.3,3)
0105                CALL PLOT(-4.95833,9.55,2)
0106                CALL PLOT(-4.95833,9.60,3)
0107                CALL PLOT(-4.95833,9.70,2)
0108                CALL PLOT(-4.95833,9.75,3)
0109                CALL PLOT(-4.95833,10.0,2)
0110                X=6.03333
            C
            C       WRITE THE LEGEND FOR AGGREGATE OPACITY STANDARD ABOVE THE PLOT ON THE
            C       RIGHT HAND SIDE BELOW THE LEGEND FOR SINGLE EVENT STANDARD
            C
0111                CALL SYMBOL(-4.69444,X,.116667,'AGGREGATE OPACITY STANDARD',90.0
                    1,26)
0112                CALL PLOT(-4.75,9.3,3)
0113                CALL PLOT(-4.75,9.4,2)
0114                CALL PLOT(-4.75,9.45,3)
0115                CALL PLOT(-4.75,9.55,2)
0116                CALL PLOT(-4.75,9.6,3)
0117                CALL PLOT(-4.75,9.7,2)
0118                CALL PLOT(-4.75,9.75,3)
0119                CALL PLOT(-4.75,9.85,2)
0120                CALL PLOT(-4.75,9.9,3)
0121                CALL PLOT(-4.75,10.0,2)
            C
            C       WRITE THE LEGEND FOR CALCULATED OPACITY PLUS OR MINUS STANDARD DEVIATION
            C       ABOVE THE PLOT IN THE CENTER
            C
0122                Y=4.86111
0123                X=2.0
0124                CALL PLOT(DY-Y,X-DX,3)
0125                CALL PLOT(-Y-DX,X+DX,2)
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 0126                CALL PLOT(-Y-DY,X-DX,3)
 0127                CALL PLOT(DY-Y,X+DX,2)
 0128                CALL PLOT(-4.70833,X-DX,3)
 0129                CALL PLOT(-4.70833,X+DX,2)
 0130                CALL PLOT(-4.70833,X,3)
 0131                CALL PLOT(-5.01389,X,2)
 0132                CALL PLOT(-5.01389,X-DX,2)
 0133                CALL PLOT(-5.01389,X+DX,2)
 0134                X=2.15
 0135                CALL SYMBOL(-4.90278,X,.116667,'CALCULATED OPACITY PLUS OR'
                     1,90.0,26)
 0136                CALL SYMBOL(-4.69444,X,.116667,'MINUS TWO STANDARD DEVIATIONS'
                     1,90.0,29)
 0137                Y=.416667
               C
               C     REDEFINE THE ORIGIN FOR PLOTTING
               C
 0138                CALL PLOT(-Y,0.0,-3)
               C
               C     DRAW A LONG DASHED LINE AT THE 0% OPACITY LEVEL
               C
 0139                DO 90 I=1,75
 0140                IP=2
 0141                IF(MOD(I,4).EQ.0)IP=3
 0142                X=I*.133333
 0143                CALL PLOT(0.0,X,IP)
 0144          90    CONTINUE
               C
               C     DRAW A SHORT DASHED LINE AT THE AGGREGATE OPACITY STANDARD VALUE
               C
 0145                Y=VAVE*.0416667
 0146                CALL PLOT(-Y,0.0,3)
 0147                DO 100 I=1,200
 0148                IP=2
 0149                IF(MOD(I,3).EQ.0)IP=3
 0150                X=I*.050
 0151                CALL PLOT(-Y,X,IP)
 0152          100   CONTINUE
               C
               C     DRAW A LONG-SHORT DASHED LINE AT THE SINGLE EVENT OPACITY STANDARD
               C     VALUE
               C
 0153                Y=VSIN*.0416667
 0154                CALL PLOT(-Y,0.0,3)
 0155                DO 110 I=1,200
 0156                IP=2
 0157                IF(MOD(I+3,12).EQ.0.OR.MOD(I,12).EQ.0)IP=3
 0158                X=I*.0500
 0159                CALL PLOT(-Y,X,IP)
 0160          110   CONTINUE
               C
               C     BEGINNING TIME FOR THE CURRENT PLOT IN MINUTES
               C
 0161                BTIM=IBTIM(1)*60.0+IBTIM(2)
 0162                TTT=ETIM          !REPORT END TIME
               C
```

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FORTRAN IV-PLUS V02-51E          14:40:08    23-MAR-81           PAGE 6
OMEGA8.FTN        /TR:BLOCKS/WR

            C       IF THE REPORT INTERVAL INCLUDES MIDNIGHT, ADD 1440 TO TTT, THE
            C       END OF THE REPORT INTERVAL
            C
0163                IF(TTT.LT.BTIM)TTT=TTT+1440.0
0164                PETIM=BTIM+10.0           !END OF THE CURRENT PLOT
            C
            C       IF THE END OF THE REPORT INTERVAL OCCURS BEFORE THE END OF THE CURRENT
            C       PLOT, SET PETIM EQUAL TO TTT
            C
0165                IF(PETIM.GE.TTT)PETIM=TTT
            C
            C       PTIM IS THE TIME OF THE CURRENT SHOT IN MINUTES
            C
0166        120     PTIM=60.0*IREP(4,JCNT)+IREP(5,JCNT)+IREP(6,JCNT)/60.0
0167                PPTIM=PTIM
            C
            ?
            ?
            C       MIDNIGHT CORRECTION
            C
0168                IF(PETIM.GT.1440.0.AND.PTIM.LE.PETIM-1440.0)PTIM=PTIM+1440.0
            C
            C       IF THE POINT IS AT THE END OR OUTSIDE OF THE CURRENT PLOT INTERVAL
            C       CLOSE THE PLOT AND OPEN ANOTHER ONE IF THERE IS STILL MORE DATA
            C       TO BE PLOTTED.  (GO TO 170)
            C
0169                IF(PTIM.GE.PETIM)GOTO 170
            C
            C       IF THE POINT OCCURS BEFORE THE CURRENT PLOT INTERVAL, GO GET THE NEXT
            C       POINT
            C
0170                IF(PTIM.LT.BTIM)GOTO 160
            C
            C       IF 'SO' FOR THIS POINT IS TOO BIG, GET THE NEXT POINT
            C
0171                ITOTAL=ITOTAL+1
0172        130     IF(REP(11,JCNT).LT.8.5)GOTO 135
0173                IHISO=IHISO+1
0174                GOTO 160
            C
            C       GET THE X AND Y COORDINATES FOR PLOTTING
            C
0175        135     X=PTIM-BTIM
0176                Y=REP(10,JCNT)*.0416667
            C
            C       FORCE OPACITIES LESS THAN ZERO TO ZERO
            C
0177                IF(Y.LT.0.0)Y=0.0
            C
            C       CONVERT 'SO' TO PLOTTING COORDINATES
            C
0178                DELY=2.0*REP(11,JCNT)*.0416667
            C
            C       PLOT THE OPACITY PLUS OR MINUS TWO STANDARD DEVIATIONS WITH AN 'X' MARK-
            C       ING THE OPACITY AND AN ERROR BAR INDICATING TWO STANDARD DEVIATIONS.
            C
```

```
FORTRAN IV-PLUS V02-51E        14:40:08    23-MAR-81           PAGE 7
OMEGA8.FTN        /TR:BLOCKS/WR

0179               CALL PLOT(DY-Y,X-DX,3)
0180               CALL PLOT(-Y-DY,X+DX,2)
0181               CALL PLOT(-Y-DY,X-DX,3)
0182               CALL PLOT(DY-Y,X+DX,2)
0183               CALL PLOT(DELY-Y,X-DX,3)
0184               CALL PLOT(DELY-Y,X+DX,2)
0185               CALL PLOT(DELY-Y,X,3)
0186               CALL PLOT(-Y-DELY,X,2)
0187               CALL PLOT(-Y-DELY,X-DX,2)
0188               CALL PLOT(-Y-DELY,X+DX,2)
0189               IF(LINE.GT.1)GOTO 140
          C
          C        THIS IS THE FIRST LINE ON THE REPORT PAGE.  WRITE THE HEADER FIRST
          C
0190               WRITE(6,1140)
0191               WRITE(6,1150)TITLE
0192               WRITE(6,1160)
          C
          C        PRINT THE INFORMATION FROM THIS SHOT IN THE REPORT
          C
0193      140      C=REP(10,JCNT)  !OPACITY
0194               D=REP(11,JCNT)  !SO
0195               IF(C.LT.0.0)C=0.0
0196               IF(C-2.0*D.LT.VAVE)GOTO 144
0197               IFLAG=IFLAG+1
0198               IF(AFLG)GOTO 142
0199               AFLG=.TRUE.
0200      141      ASTIM=PPTIM
0201               ALTIM=PPTIM
0202               GOTO 150
0203      142      IF(PPTIM.LT.ASTIM)PPTIM=PPTIM+1440.
0204               IF(PPTIM-ALTIM.LT.0.33)GOTO 143
0205               ATIM=ATIM+AETIM
0206               AETIM=0.0
0207               GOTO 141
0208      143      ALTIM=PPTIM
0209               AETIM=PPTIM-ASTIM
0210               GOTO 150
0211      144      IF(.NOT.AFLG)GOTO 150
0212               AFLG=.FALSE.
0213               ATIM=ATIM+AETIM
0214               AETIM=0
0215      150      TTIM=ATIM+AETIM
          C
          C        CHANGE THE OPACITY AND SO TOO INTEGERS
          C
0216               ENCODE(15,1170,SCR)C,D
0217               DECODE(15,1180,SCR)IC,ID
0218               WRITE(6,1190)(IREP(M,JCNT),M=1,6),IC,ID,TTIM,IHISO,ITOTAL
          C
          C        INDICATE NONCOMPLIANCE WITH STANDARDS FOR AGGREGATE OR SINGLE EVENT
          C        WITH ASTERISKS
          C
0219               IF(REP(10,JCNT)-2.*REP(11,JCNT).GE.VSIN)WRITE(6,1200)
0220               IF(C-2.*REP(11,JCNT).GE.VAVE)WRITE(6,1210)
          C
```

```
C       INCREMENT THE LINE COUNTER, 50 LINES PER PAGE
C
        LINE=LINE+1
        IF(LINE.GT.50)LINE=1
C
C       INCREMENT THE INPUT ARRAY COUNTER.  IF THERE IS NO MORE DATA IN THE
C       INPUT ARRAY, READ ANOTHER FILE IN.
C
160     JCNT=JCNT+1
        IF(JCNT.LE.ICNT)GOTO 120
        CALL SOURCE
        JCNT=1
C
C       IF ANOTHER INPUT FILE WAS NOT SPECIFIED WE ARE DONE.
C
        IF(ICNT.EQ.0)GOTO 190
        GOTO 120
170     IF(PTIM.GT.PETIM)GOTO 180
C
C       IF THIS POINT IS AT THE END OF THE CURRENT PLOT AND AT THE END OF
C       THE REPORT INTERVAL, PUT IT ON THIS PLOT.
C
        IF(PTIM.EQ.TTT)GOTO 130
C
C       CURRENT PLOT IS FINISHED.  CLOSE IT OUT.
C
180     CALL PLOTND
C
C       INCREMENT BEGINNING TIME FOR THE NEXT PLOT
C
        IBTIM(2)=IBTIM(2)+10
        IF(IBTIM(2).LT.60)GOTO 185
        IBTIM(2)=IBTIM(2)-60
        IBTIM(1)=IBTIM(1)+1
        IF(IBTIM(1).EQ.24)IBTIM(1)=0
185     TT=60.0*IBTIM(1)+IBTIM(2)
        IF(TT.GE.TTT)GOTO 190
C
C       INCREMENT THE PLOT FILE COUNTER AND GET THE NEXT PLOT FILE SPECIFICATION
C       (VECTOR FILE)
C
188     IPCNT=IPCNT+1
        CALL WAIT(3,2,IWSTAT)    !WAIT FOR PLOTND TO CLOSE THE OLD VECTOR FILE
        GOTO 20          !GET NEXT PLOT FILE
C
C       END OF PROGRAM, CLOSE THE CURRENT PLOT FILE AND EXIT
C
190     CALL PLOTND
        CALL WAIT(3,2,IWSTAT)
        CALL EXIT
C
C       FORMAT STATEMENTS
C
1000    FORMAT(' THIS PROGRAM MAKES TABLES AND PLOTS OF LIDAR OPACITY',
        1' DATA GENERATED BY OMEGA5.'//)
1010    FORMAT('$ENTER REPORT START TIME: HOURS, MINUTES ')
```

```
FORTRAN IV-PLUS V02-51E        14:40:08    23-MAR-81          PAGE 9
OMEGAB.FTN       /TR:BLOCKS/WR

        1020     FORMAT('$ENTER REPORT STOP TIME: HOURS, MINUTES ')
        1030     FORMAT('$WILL DATA BE AVERAGED? ')
        1040     FORMAT(20A2)
        1050     FORMAT('$ENTER AGGREGATE PERIOD IN MINUTES: ')
        1060     FORMAT('$ENTER STANDARDS FOR AGGREGATE, SINGLE EVENT: ')
        1070     FORMAT(' ENTER TABLE TITLE.  100 CHARACTERS MAXIMUM.')
        1080     FORMAT(20A4/13A4)
        1090     FORMAT(' ENTER PLOT TITLE.  50 CHARACTERS MAXIMUM.')
        1100     FORMAT(Q,26A2)
        1110     FORMAT('$ENTER FILE SPECIFICATION FOR PLOT FILE NUMBER',I3,1X)
        1120     FORMAT(I2,':',I2,3X)
        1130     FORMAT(I3,3X)
        1140     FORMAT(1H1,44X,'UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'
                 1/46X,'NATIONAL ENFORCEMENT INVESTIGATIONS CENTER'
                 2/56X,'DENVER, COLORADO 80225'//)
        1150     FORMAT(16X,25A4)
        1160     FORMAT(18X,'DATE',6X,'TIME    OPACITY   SO  NONCOMPLIANCE ',
                 1'  AGGREGATE  AGGREGATE TIME FLAGGED  NUMBER DISCARDED'/)
        1170     FORMAT(1X,F7.0,F7.0)
        1180     FORMAT(I7,1X,I6)
        1190     FORMAT(16X,I2,'/',I2,'/',I2,I4,':',I2,':',I2,3X,I4,4X,I3
                 1,31X,F7.2,' MINUTES',10X,I3,' OF',I4)
        1200     FORMAT(1H+,T55,'****')
        1210     FORMAT(1H+,T69,'****')
        1220     FORMAT('DATE: ',I2,'/',I2,'/',I2)
                 END
```

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FORTRAN IV-PLUS V02-51E          14:40:08    23-MAR-81          PAGE 10
OMEGAB.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                  ATTRIBUTES

  1     $CODE1  006772  1789               RW,I,CON,LCL
  2     $PDATA  000570   188               RW,D,CON,LCL
  3     $IDATA  002516   679               RW,D,CON,LCL
  4     $VARS   000664   218               RW,D,CON,LCL
  5     $TEMPS  000020     8               RW,D,CON,LCL
  6     .$$$$.  070206 14403               RW,D,OVR,GBL

VARIABLES

 NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS      NAME   TYPE  ADDRESS

 AETIM  R*4   4-000542     AFLG   L*1   4-000476     ALTIM  R*4   4-000640     ASTIM  R*4   4-000634     ATIM   R*4   4-000536
 AVE    R*4   4-000502     BTIM   R*4   4-000574     C      R*4   4-000624     D      R*4   4-000630     DELY   R*4   4-000620
 DX     R*4   4-000506     DY     R*4   4-000512     ETIM   R*4   4-000520     I      I*2   4-000556     IC     I*2   4-000650
 ICNT   I*2   6-070204     ID     I*2   4-000652     IFLAG  I*2   4-000552     IHISO  I*2   4-000550     IP     I*2   4-000572
 IPCNT  I*2   4-000500     ISCNT  I*2   6-070200     ISHCT  I*2   6-070202     ITOTAL I*2   4-000546     IWSTAT I*2   4-000662
 JCNT   I*2   4-000516     LINE   I*2   4-000554     M      I*2   4-000654     NCHR   I*2   4-000534     NUM    I*2   4-000570
 PETIM  R*4   4-000604     PPTIM  R*4   4-000614     PTIM   R*4   4-000610     TT     R*4   4-000656     TTIM   R*4   4-000644
 TTT    R*4   4-000600     VAVE   R*4   4-000524     VSIN   R*4   4-000530     X      R*4   4-000560     Y      R*4   4-000564

ARRAYS

 NAME   TYPE  ADDRESS          SIZE         DIMENSIONS

 IBTIM  I*2   4-000000  000004     2        (2)
 IETIM  I*2   4-000004  000004     2        (2)
 INUM   I*2   4-000350  000006     3        (3)
 IPFILE I*2   4-000240  000024    10        (10)
 IPTITL I*2   4-000154  000064    26        (26)
 IREP   I*2   6-047300  020700  4320        (12,360)
 ISCR   I*2   4-000264  000050    20        (20)
 ISTIM  I*2   4-000344  000004     2        (2)
 IWTIM  I*2   4-000334  000010     4        (4)
 REP    R*4   6-000000  047300 10080        (14,360)
 SCR    R*4   4-000356  000120    40        (20)
 TITLE  R*4   4-000010  000144    50        (25)

LABELS

 LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS          LABEL  ADDRESS

 10        **            20     1-000614         30        **            40        **            50        **
 60        **            70     1-001704         80        **            90        **            100       **
 110       **            120    1-004262         130    1-004444         135    1-004510         140    1-005450
 141    1-005556         142    1-005604         143    1-005702         144    1-005734         150    1-005776
 160    1-006436         170    1-006514         180    1-006560         185    1-006642         188       **
 190    1-006730         1000'  3-000000         1010'  3-000126         1020'  3-000202         1030'     **
 1040'  3-000256         1050'  3-000262         1060'  3-000332         1070'  3-000414         1080'  3-000474
 1090'  3-000504         1100'  3-000562         1110'  3-000570         1120'  3-000654         1130'  3-000666
```

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FORTRAN IV-PLUS V02-51E          14:40:08    23-MAR-81          PAGE 11
OMEGAB.FTN       /TR:BLOCKS/WR

 1140'   3-000674         1150'   3-001074        1160'   3-001102        1170'   3-001254        1180'   3-001264
 1190'   3-001272         1200'   3-001364        1210'   3-001400        1220'   3-001414

FUNCTIONS AND SUBROUTINES REFERENCED

 EXIT    NEWDEV  PLOT    PLOTND  PLOTST  SOURCE  SYMBOL  WAIT

TOTAL SPACE ALLOCATED = 103412 17285
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FORTRAN IV-PLUS V02-51E          14:40:30    23-MAR-81           PAGE 12
OMEGAB.FTN        /TR:BLOCKS/WR

0001                    SUBROUTINE SOURCE
                C
                C       THIS SUBROUTINE READS DATA FROM A DESIGNATED DISC FILE
                C       INTO REP AND IREP
                C
0002                    COMMON REP(14,360),IREP(12,360),ISCNT,ISHOT,ICNT
0003                    DIMENSION ISFILE(10),IAUX(52)
                C
                C       GET THE FILE SPECIFICATION FOR INPUT FILE NUMBER ISCNT
                C
0004            10      WRITE(5,1000)ISCNT
C005                    READ(5,1010)ISFILE
0006                    IF(ISFILE(2).EQ.'  ')GOTO 120
0007                    ISFILE(10)=0
0008                    CALL CLOSE(3)
0009                    OPEN(UNIT=3,NAME=ISFILE,TYPE='OLD',READONLY,ERR=20
                        1,DISPOSE='SAVE')
0010                    GOTO 30
                C
                C       HERE IF ERROR OPENING DISC FILE
                C
0011            20      WRITE(5,1020)
0012                    GOTO 10
                C
                C       READ HEADER INFORMATION
                C
0013            30      READ(3,1030)IAUX
                C
                C       DISPLAY THE HEADER INFORMATION ON THE TERMINAL
                C
0014                    WRITE(5,1040)IAUX(7),(IAUX(I),I=1,6),IAUX(8),IAUX(9)
0015                    WRITE(5,1050)(IAUX(I),I=21,52)
                C
                C       READ DATA INTO THE INPUT ARRAYS
                C
0016                    DO 40 I=1,360
0017                    READ(3,1060,END=50)(IREP(L,I),L=1,12),(REP(L,I),L=1,14)
0018            40      CONTINUE
0019            50      CALL CLOSE(3)
0020                    ICNT=I-1          !NUMBER OF SHOTS IN THE INPUT FILE
                C
                C       TELL THE OPERATOR WHICH SHOTS ARE INCLUDED IN THIS FILE AND
                C       VERIFY THAT THIS IS THE CORRECT FILE.
                C
0021                    WRITE(5,1070)ISHOT,IREP(7,1),IREP(7,ICNT)
0022                    READ(5,1010)IC
0023                    IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
0024                    IF(ISCNT.EQ.1)GOTO 60
                C
                C       CHECK TO SEE THAT THIS FILE INCLUDES THE NEXT SHOT.  IF IT DOES NOT,
                C       TELL THE OPERATOR AND VERIFY THAT THIS IS THE CORRECT FILE.
                C
0025                    IF(IREP(7,1).LE.ISHOT+1.AND.IREP(7,ICNT).GE.ISHOT+1)GOTO 60
0026                    WRITE(5,1080)
0027                    READ(5,1010)IC
0028                    IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
```

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FORTRAN IV-PLUS V02-51E         14:40:30    23-MAR-81           PAGE 13
OMEGAB.FTN      /TR:BLOCKS/WR

0029     60       ISCNT=ISCNT+1
         C
         C        IF THIS IS THE FIRST FILE, KEEP ALL THE DATA.
         C
0030              IF(ISCNT.EQ.2)GOTO 110
0031              IF(ISHOT.LT.IREP(7,1))GOTO 110
         C
         C        IF THIS IS NOT THE FIRST FILE, KEEP ONLY THE DATA WHICH HAS NOT
         C        ALREADY BEEN PLOTTED.
         C
0032              DO 70 I=1,ICNT
0033              IF(ISHOT.EQ.IREP(7,I))GOTO 80
0034     70       CONTINUE
0035              I=I-1
0036     80       DO 100 J=1,ICNT-I
0037              DO 90 K=1,12
0038              IREP(K,J)=IREP(K,J+I)
0039              REP(K,J)=REP(K,J+I)
0040     90       CONTINUE
0041              REP(13,J)=REP(13,J+I)
0042              REP(14,J)=REP(14,J+I)
0043     100      CONTINUE
0044              ICNT=ICNT-I
0045     110      ISHOT=IREP(7,ICNT)
0046              RETURN
         C
         C        NO INPUT FILE WAS SPECIFIED.  VERIFY THAT NO NEW FILE IS DESIRED,
         C        AND RETURN WITH THE FILE SIZE SET TO ZERO.
         C
0047     120      WRITE(5,1090)
0048              READ(5,1010)IC
0049              IF(IC.NE.'Y '.AND.IC.NE.'YE')GOTO 10
0050              ICNT=0
0051              RETURN
         C
         C        FORMAT STATEMENTS
         C
0052     1000     FORMAT(' ENTER FILE SPECIFICATION FOR SOURCE FILE NUMBER',I3,1X)
0053     1010     FORMAT(20A2)
0054     1020     FORMAT(' ERROR OPENING DISC FILE!')
0055     1030     FORMAT(1X,6I2,3I4,A2,I5,I4,2I5,I3,2I5,2I3,I4,32A2)
0056     1040     FORMAT(/' FILE',I5,I4,'/',I2,'/',I2,I4,':',I2,':',I2,2X,
                 1'REF. FILE',I5,2X,'GATE CALIBRATION FILE',I5/)
0057     1050     FORMAT(1X,32A2/)
0058     1060     FORMAT(1X,6I2,4I5,2I3,13F5.1,F7.3)
0059     1070     FORMAT(' LAST SHOT WAS:',I5,'  THIS FILE STARTS AT SHOT',I5,
                 1' AND RUNS TO SHOT',I5/'$IS THIS THE RIGHT FILE? ')
0060     1080     FORMAT('$THIS FILE DOES NOT INCLUDE THE NEXT SHOT.',
                 1'  ARE YOU SURE IT''S THE RIGHT ONE? ')
0061     1090     FORMAT('$ARE WE DONE? ')
0062              END
```

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FORTRAN IV-PLUS V02-51E           14:40:30    23-MAR-81          PAGE 14
OMEGA8.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER  NAME       SIZE                  ATTRIBUTES

  1     $CODE1   001744   498            RW,I,CON,LCL
  2     $PDATA   000004     2            RW,D,CON,LCL
  3     $IDATA   000714   230            RW,D,CON,LCL
  4     $VARS    000206    67            RW,D,CON,LCL
  5     $TEMPS   000012     5            RW,D,CON,LCL
  6     .$$$$.   070206 14403            RW,D,OVR,GBL

ENTRY POINTS

 NAME    TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 SOURCE        1-000000

VARIABLES

 NAME    TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS    NAME   TYPE  ADDRESS

 I       I*2   4-000174   IC     I*2   4-000200   ICNT   I*2   6-070204   ISCNT  I*2   6-070200   ISHOT  I*2   6-070202
 J       I*2   4-000202   K      I*2   4-000204   L      I*2   4-000176

ARRAYS

 NAME    TYPE  ADDRESS       SIZE          DIMENSIONS

 IAUX    I*2   4-000024  000150     52     (52)
 IREP    I*2   6-047300  020700   4320     (12,360)
 ISFILE  I*2   4-000000  000024     10     (10)
 REP     R*4   6-000000  047300  10080     (14,360)

LABELS

 LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS

 10      1-000014        20      1-000150        30      1-000200        40         **           50      1-000660
 60      1-001176        70         **           80      1-001304        90         **           100        **
 110     1-001606        120     1-001634        1000'   3-000000        1010'   3-000066        1020'   3-000072
 1030'   3-000126        1040'   3-000164        1050'   3-000276        1060'   3-000304        1070'   3-000326
 1080'   3-000472        1090'   3-000614

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSE   OPEN$

TOTAL SPACE ALLOCATED = 073312 15205

SYO:[101,1]OMEGA8,SYO:[101,1]OMEGA8/-SP=SYO:[101,1]OMEGA8
```

B(e) Lidar Eyesafe Program (FORTRAN-4+, HP Language and Variable Dictionary)

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FORTRAN IV-PLUS V02-51E        08:16:14    11-MAR-81          PAGE 1
EYESAF.FTN      /TR:BLOCKS/WR

         C       PROGRAM LIDAR EYESAFE--OUTPUT TO VT-100 AND PRINTER
         C
         C       THIS PROGRAM CALCULATES THE INTEGRATED OPTICAL ATMOSPHERIC EXTINCTION
         C       COEFFICIENT ALONG THE LIDAR LINE-OF-SIGHT, AND THE METEOROLOGICAL
         C       VISUAL RANGE AS A FUNCTION OF THIS EXTINCTION COEFFICIENT.
         C
         C       THEN HAVING THE ACTUAL RANGE OF THE VISIBLE EMISSIONS SOURCE FROM
         C       THE LIDAR, THE OPACITY OF THE PLUME UNDER-TEST AND THE ATMOSPHERIC
         C       EXTINCTION COEFFICIENT, THE APPROXIMATE EYESAFE DISTANCE (DIRECT
         C       IN-BEAM VIEWING) IS CALCULATED, AND REPORTED IN KILOMETERS, STATUTE
         C       MILES AND NAUTICAL MILES.
         C
         C       SECTION A--THIS SECTION OF THE PROGRAM CALCULATES THE INTEGRATED
         C               OPTICAL ATMOSPHERIC EXTINCTION COEFFICIENT, BETA.
         C
         C       USING A CLEAR-AIR RETURN SIGNAL ON THE LIDAR'S OSCILLOSCOPE DISPLAY,
         C       SELECT TWO POINTS OF THE CURVE (SEE ATTACHED PHOTO), CALLING THEM
         C       P(1) AND P(2), WITH P(1) BEING THE CLOSER ONE TO T(0).
         C
         C
         C       T(1) IS THE ABSCISSA VALUE IN TIME FOR THE POINT P(1).
         C       T(2) IS THE ABSCISSA VALUE IN TIME FOR THE POINT P(2).
         C       I(1) IS THE ORDINATE VALUE IN AMPLITUDE FOR THE POINT P(1).
         C       I(2) IS THE ORDINATE VALUE IN AMPLITUDE FOR THE POINT P(2).
         C
         C       THE HORIZONTAL TIME SCALE ON THE OSCILLOSCOPE IS IN NANOSECONDS
         C       WHICH IS THE DISPLAY ABSCISSA.
         C
         C       ENTER THE OSCILLOSCOPE DISPLAY ABSCISSA VALUE IN NANOSEC/CM.
         C
0001             REAL*8 C
         C
0002             WRITE (6,9)
0003          9  FORMAT (/,' *   *   * LIDAR EYESAFE PROGRAM OUTPUT *   *   *')
         C
0004             TYPE 10
0005         10  FORMAT (/,'$ENTER # OF NANOSEC/CM FROM OSCILLOSCOPE = ')
0006             ACCEPT *,NS
         C
0007             WRITE (6,11) NS
0008         11  FORMAT (/,' NO OF NANOSEC FROM OSCILLOSCOPE = ',I6,' NANOSEC')
         C
         C       POINT OF ENTRY FOR DISPLAY VALUES WHICH ARE IN CM,
         C       ABSCISSA VALUES FIRST.
         C
0009             TYPE 12
0010         12  FORMAT ('$ENTER # OF CM FOR T(1) IN X.XX CM = ')
0011             ACCEPT *,T1
         C
0012             WRITE (6,13) T1
0013         13  FORMAT (/,' NUMBER OF CM FOR T(1) = ',F5.2,' CM')
         C
0014             TYPE 14
0015         14  FORMAT ('$ENTER # OF CM FOR T(2) IN X.XX CM = ')
0016             ACCEPT *,T2
         C
```

```
0017                WRITE (6,15) T2
0018          15    FORMAT (/,' NUMBER OF CM FOR T(2) = ',F5.2,' CM')
           C
0019                TYPE 16
0020          16    FORMAT ('$ENTER # OF CM FOR I(1) IN X.XX CM = ')
0021                ACCEPT *,AMP1
           C
0022                WRITE (6,17) AMP1
0023          17    FORMAT (/,' NUMBER OF CM FOR I(1) = ',F5.2,' CM')
           C
0024                TYPE 18
0025          18    FORMAT ('$ENTER # OF CM FOR I(2) IN X.XX CM = ')
0026                ACCEPT *,AMP2
           C
0027                WRITE (6,19) AMP2
0028          19    FORMAT (/,' NUMBER OF CM FOR I(2) = ',F5.2,' CM')
           C
0029                C=29979245620.          !C IS THE SPEED OF LIGHT IN CM PER SEC
           C
           C
0030                RAT=T1/T2
0031                AMP=AMP2/AMP1
0032                TNS1=T1*NS
0033                TNS2=T2*NS
           C
0034                DELT=TNS2-TNS1          !DELT IS IN NANOSEC
0035                SDELT=DELT*(1.E-9)         !SDELT IS IN SECONDS
0036                CDELT=SDELT*C/2.           !CDELT  IS C(T2-T1)/2 IN CM
0037                DELTC=1./CDELT
           C
           C        NOW THE EXTINCTION COEFFICIENT BETA IS CALCULATED.
           C
0039                BETA=DELTC*(ALOG(RAT)-1.152*ALOG10(AMP))
           C
0039                WRITE (5,20) BETA
0040                WRITE (6,20) BETA
0041          20    FORMAT (/,' BETA = ',E12.4,' INVERSE CM')
           C
0042                BETAC=BETA
           C
           C
           C        SECTION B--THIS SECTION OF THE PROGRAM CALCULATES THE METEOROLOGICAL
           C                   VISUAL RANGE IN KILOMETERS, STATUTE MILES AND NAUTICAL
           C                   MILES.
           C
0043                RMVRK=3.915*(1.E-5)/BETAC        !RMVR IS IN KILOMETERS
           C
0044                RMVRS=2.433*(1.E-5)/BETAC        !RMVR IS IN STATUTE MILES
           C
0045                RMVRN=2.113*(1.E-5)/BETAC        !RMVR IS IN NAUTICAL MILES
           C
0046                WRITE (5,22) RMVRK
0047                WRITE (6,22) RMVRK
0048          22    FORMAT (/,' RMVR = ',F6.0,' KILOMETERS')
           C
0049                WRITE (5,24) RMVRS
```

```
0050                 WRITE (6,24) RMVRS
0051            24   FORMAT (/,' RMVR = ',F6.0,' STATUTE MILES')
              C
0052                 WRITE (5,26) RMVRN
0053                 WRITE (6,26) RMVRN
0054            26   FORMAT (/,' RMVR = ',F6.0,' NAUTICAL MILES')
              C
              C
              C      SECTION C--THIS SECTION OF THE PROGRAM CALCULATES THE APPROXIMATE
              C
              C                EYESAFE DISTANCE (DIRECT IN-BEAM VIEWING) IN KILOMETERS,
              C                STATUTE MILES AND NAUTICAL MILES.
              C
              C
              C      HAVING THE LASER OUTPUT ENERGY, BEAM DIAMETER OUT OF THE UPCOLLIMATOR
              C      AND THE BEAM DIVERGENCE ANGLE OUT OF THE UPCOLLIMATOR, IN ADDITION TO
              C      THE ATMOSPHERIC EXTINCTION COEFFICIENT AND THE LIDAR RANGE TO THE
              C      STACK, THE IN-BEAM RADIANT EXPOSURE AND THE BEAM ENERGY/PULSE IS
              C      ARE CALCULATED AT THE PLUME UNDER-TEST.
              C
              C      ENTER THE TIME SCALE FROM THE OSCILLOSCOPE USED FOR THIS MEASUREMENT
              C      IN NANOSEC/CM.  IF THE SAME AS NS ENTERED AT THE BEGINNING OF THIS
              C      PROGRAM, ENTER THE SAME VALUE.
              C
0055                 TYPE 28
0056            28   FORMAT (/,'$ENTER # OF NANOSEC/CM FROM OSCILLOSCOPE = ')
0057                 ACCEPT *,NNS
              C
0058                 WRITE (6,29) NNS
0059            29   FORMAT (/,' NO OF NANOSEC/CM FROM SCOPE = ',I6,' NANOSEC')
              C
              C      T(O) IS THE TIME OF SYSTEM TRIGGER IN THE LIDAR, USUALLY 620-750 NANOSEC
              C
0060                 TYPE 30
0061            30   FORMAT (/,'$ENTER VALUE OF T(O) IN NANOSEC = ')
0062                 ACCEPT *,TO
              C
0063                 WRITE (6,31) TO
0064            31   FORMAT (/,' VALUE OF T(O) = ',F6.0,' NANOSECONDS')
              C
              C      RS IS THE RANGE TO THE STACK UNDER-TEST OBTAINED FROM THE OSCILLOSCOPE.
              C
0065                 TYPE 32
0066            32   FORMAT (/,'$ENTER # OF CM FOR STACK RANGE IN X.XX CM = ')
0067                 ACCEPT *,RSCM
              C
0068                 WRITE (6,33) RSCM
0069            33   FORMAT (/,' NUMBER OF CM FOR STACK RANGE = ',F5.2,' CM')
              C
0070                 RNS=RSCM*NNS             !RNS IS IN NANOSECONDS
0071                 RSN=RNS-TO               !RSN IS IN NANOSECONDS WITH T(O) REMOVED
0072                 RSS=RSN*(1.E-9)          !RSS IS IN SECONDS
0073                 RS=RSS*C/2.              !RS IS IN CM
0074                 RSM=RS/100.              !RSM IS IN METERS
              C
              C      A IS THE LASER BEAM EXIT DIAMETER OUT OF THE UPCOLLIMATOR.
```

```
FORTRAN IV-PLUS V02-51E          08:16:14     11-MAR-81          PAGE 4
EYESAF.FTN         /TR:BLOCKS/WR

              C
0075                   A=4.0              !THE DIAMETER IS GIVEN IN CM
              C
              C        PHI IS THE LASER BEAM ANGULAR DIVERGENCE VALUE.
              C
0076                   PHI=2.E-4          !DIVERGENCE OUT OF THE UPCOLLIMATOR IS 0.2 MILLIRADIANS
              C
0077                   DRS=A+100.*PHI*RSM        !DRS IS THE BEAM DIAMETER AT THE STACK IN CM
              C
              C
              C        HS IS THE LASER BEAM RADIANT EXPOSURE AT THE STACK.
              C
              C        Q IS THE OUTPUT ENERGY OF THE LASER IN JOULES/PULSE.
              C
0078                   TYPE 34
0079              34   FORMAT (/,'$ENTER LASER OUTPUT ENERGY IN JOULES/PULSE = ')
0080                   ACCEPT *,Q
              C
0081                   WRITE (6,35) Q
0082              35   FORMAT (/,' LASER OUTPUT ENERGY = ',F5.1,' JOULES/PULSE')
              C
0083                   HS=(1.27*Q*(EXP(-100.*BETAC*RSM)))/(DRS**2.)
              C
              C        THE LASER BEAM RADIANT EXPOSURE VALUE IS MODIFIED BY THE OPACITY
              C        VALUE OF THE PLUME UNDER-TEST.
              C
0084                   TYPE 36
0085              36   FORMAT (/,'$ENTER PLUME OPACITY VALUE IN % = ')
0086                   ACCEPT *,OP
              C
0087                   WRITE (6,37) OP
0088              37   FORMAT (/,' PLUME OPACITY VALUE = ',F5.0,' %')
              C
0089                   OPP=OP/100.        !CONVERT OP IN % TO AN EQUIVALENT DECIMAL
              C
0090                   TP=1.-OPP
              C
0091                   HOPS=HS*TP         !RADIANT EXPOSURE ON THE BACK SIDE OF THE PLUME
              C
0092                   AIO=Q              !LASER OUTPUT ENERGY-CHANGE OF VARIABLE
              C        THE ENERGY OF THE LASER PULSE IS CALCULATED AT THE PLUME.
              C
0093                   AIS=AIO*(EXP(-100.*BETAC*RSM))  !BEAM ENERGY AT THE STACK
              C
              C        THE LASER BEAM ENERGY AT THE STACK IS MODIFIED BY THE OPACITY
              C        VALUE OF THE PLUME UNDER-TEST.
              C
0094                   AISP=AIS*TP        !LASER ENERGY ON THE BACK SIDE OF THE PLUME
              C
              C        THE LASER ENERGY (AISP) AND THE BEAM DIAMETER AT THE BACK SIDE OF
              C        THE PLUME ARE USED TO CALCULATE THE SAFE RADIANT EXPOSURE VALUE.
              C
0095                   RB=500.*100.                 !RB IS THE RANGE BEHIND THE STACK-500 M BEGIN
0096              38   CONTINUE                     !BEGINNING OF LOOP FOR RANGE CALCULATION
              C
0097                   RB=RB+500.*100.  !INCREMENT LIDAR RANGE BEHIND PLUME BY 500 METERS
```

```
      C
            DRSB=A+PHI*RB            !BEAM DIAMETER IN BACK OF THE PLUME AT ANY RSMB
      C
            HSB=1.27*AISP*(EXP(-BETAC*RB))/(DRSB**2.)        !RADIANT EXPOSURE
      C
            IF (HSB .GT. 5.E-7) GO TO 38     !PROTECTIVE STANDARD IN JOULES/CMSQ
      C
            RKM=(RSM+RB/100.)/1000.          !RANGE IN KILOMETERS
            RSMI=0.6214*RKM                  !RANGE IN STATUTE MILES
            RNMI=0.5396*RKM                  !RANGE IN NAUTICAL MILES
      C
            WRITE (5,39) RSM
      C
            WRITE (6,39) RSM
      C
         39 FORMAT (/,' LIDAR RANGE TO THE STACK = ',F6.0,' METERS')
      C
      C
            WRITE (5,40) DRS
            WRITE (6,40) DRS
         40 FORMAT (/,' LASER BEAM DIAMETER AT THE STACK = ',F6.0,' CM')
      C
            WRITE (5,41) DRSB
            WRITE (6,41) DRSB
         41 FORMAT(/,' LASER BEAM DIAMETER AT EYESAFE DISTANCE = ',F6.0,' CM')
      C
      C
            WRITE (5,43) RKM
            WRITE (6,43) RKM
         43 FORMAT (//,' LIDAR EYESAFE DISTANCE = ',F6.0,' KILOMETERS')
      C
            WRITE (5,45) RSMI
            WRITE (6,45) RSMI
         45 FORMAT (/,' LIDAR EYESAFE DISTANCE = ',F6.0,' STATUTE MILES')
      C
            WRITE (5,48) RNMI
            WRITE (6,48) RNMI
         48 FORMAT (/,' LIDAR EYESAFE DISTANCE = ',F6.0,' NAUTICAL MILES',/)
      C
            STOP
            END
```

```
FORTRAN IV-PLUS V02-51E          08:16:14    11-MAR-81         PAGE 6
EYESAF.FTN       /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME        SIZE                ATTRIBUTES

  1     $CODE1  003142   817             RW,I,CON,LCL
  2     $PDATA  000064    26             RW,D,CON,LCL
  3     $IDATA  002444   658             RW,D,CON,LCL
  4     $VARS   000264    90             RW,D,CON,LCL

VARIABLES

 NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS     NAME   TYPE  ADDRESS

 A      R*4   4-000154    AIS    R*4   4-000224    AISP   R*4   4-000230    AIO    R*4   4-000220    AMP    R*4   4-000036
 AMP1   R*4   4-000022    AMP2   R*4   4-000026    BETA   R*4   4-000072    BETAC  R*4   4-000076    C      R*8   4-000000
 CDELT  R*4   4-000062    DELT   R*4   4-000052    DELTC  R*4   4-000066    DRS    R*4   4-000164    DRSB   R*4   4-000240
 HOPS   R*4   4-000214    HS     R*4   4-000174    HSB    R*4   4-000244    NNS    I*2   4-000116    NS     I*2   4-000010
 OP     R*4   4-000200    OPP    R*4   4-000204    PHI    R*4   4-000160    G      R*4   4-000170    RAT    R*4   4-000032
 RB     R*4   4-000234    RKM    R*4   4-000250    RMVRK  R*4   4-000102    RMVRN  R*4   4-000112    RMVRS  R*4   4-000106
 RNMI   R*4   4-000260    RNS    R*4   4-000130    RS     R*4   4-000144    RSCM   R*4   4-000124    RSM    R*4   4-000150
 RSMI   R*4   4-000254    RSN    R*4   4-000134    RSS    R*4   4-000140    SDELT  R*4   4-000056    TNS1   R*4   4-000042
 TNS2   R*4   4-000046    TP     R*4   4-000210    TO     R*4   4-000120    T1     R*4   4-000012    T2     R*4   4-000016

LABELS

 LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS         LABEL    ADDRESS

 9'       3-000000        10'      3-000066        11'      3-000146        12'      3-000232        13'      3-000302
 14'      3-000350        15'      3-000420        16'      3-000466        17'      3-000536        18'      3-000604
 19'      3-000654        20'      3-000722        22'      3-000756        24'      3-001012        26'      3-001052
 28'      3-001112        29'      3-001172        30'      3-001252        31'      3-001320        32'      3-001366
 33'      3-001446        34'      3-001522        35'      3-001604        36'      3-001662        37'      3-001730
 38       1-002302        39'      3-001772        40'      3-002046        41'      3-002126        43'      3-002216
 45'      3-002276        48'      3-002360

FUNCTIONS AND SUBROUTINES REFERENCED

 $ALG10  $ALOG   $EXP

TOTAL SPACE ALLOCATED = 006156  1591

SY0:[101,3]EYESAF,SY0:[101,3]EYESAF/-SP=SY0:[101,3]EYESAF
```

PROGRAM: LIDAR EYESAFE

Variable Dictionary

Fortran Variable Names	HPL Variable Names	Fortran Variable Names	HPL Variable Names
NS	N[1]	PHI	P
T1	T[1]	DRS	D[3]
T2	T[2]	HS	H[1]
AMP1	A[1]	Q	Q
AMP2	A[2]	OP	O[1]
RAT	R[1]	OPP	O[2]
AMP	A[3]	TP	T[6]
TNS1	T[3]	HOPS	H[2]
TNS2	T[4]	AI0	A[5]
DELT	D[1]	AIS	A[6]
SDELT	S	AISP	A[7]
CDELT	C[1]	RB	R[11]
DELTC	D[2]	DRSB	D[4]
BETA	B[1]	HSB	H[3]
BETAC	B[2]	5.E-7	Z
RMVRK	R[2]	RKM	R[12]
RMVRS	R[3]	RSMI	R[13]
RMVRN	R[4]	RNMI	R[14]
NNS	N[2]		
T0	T[5]		
RSCM	R[5]		
RNS	R[6]		
RSN	R[7]		
RSS	R[8]		
RS	R[9]		
RSM	R[10]		
A	A[4]		

```
0: "LIDAR EYESAF
 E, Lidar Eyesaf
 e Range Program
 , Rev 031181":
1: dim A[7],B[2]
 ,C[2],D[4],H[3]
 ,N[2],O[2],R[20
 ],T[6]
2: spc 7
3: fmt 1,f3.0,
 c11
4: fmt 2,f3.0,
 c14
5: fmt 3,f3.0,
 c15
6: spc 1
7: 29979245620→C
8: C/2→C
9: prt "LIDAR
 EYESAFE   PROGR
 AM OUTPUT"
10: spc 1
11: ent "# of
 nanosec/cm from
  scope",N[1]
12: prt "# of
 nanosec/cm =",
 N[1]
13: spc 1
14: ent "# of
 cm for T[1] in
 X.XX cm.",T[1]
15: prt "# of
 cm for T[1] =",
 T[1]
16: spc 1
17: ent "# of
 cm for T[2] in
 X.XX cm.",T[2]
18: prt "# of
 cm for T[2] =",
 T[2]
19: spc 1
20: ent "# of
 cm for I[1] in
 X.XX cm.",A[1]
21: prt "# of
 cm for I[1] =",
 A[1]
22: spc 1
23: ent "# of
 cm for I[2] in
 X.XX cm.",A[2]
```

```
24: prt "# of
 cm for I[2] =",
 A[2]
25: spc 1
26: T[1]/T[2]→R[
 1]
27: A[2]/A[1]→A[
 3]
28: T[1]*N[1]→T[
 3]
29: T[2]*N[1]→T[
 4]
30: T[4]-T[3]→D[
 1]
31: D[1]*tn↑(-
 9)→S
32: S*C→C[1]
33: 1/C[1]→D[2]
34: D[2]*(ln(R[1
 ])-1.152*log(A[
 3]))→B[1]
35: spc 1
36: flt 4
37: prt "Beta
 =",B[1]," inver
 se cm"
38: fxd 2
39: B[1]→B[2]
40: spc 1
41: fxd 0
42: prt "Meteoro
 logical  Visual
  Range:"
43: 3.915*tn↑(-
 5)/B[2]→R[2]
44: 2.433*tn↑(-
 5)/B[2]→R[3]
45: 2.113*tn↑(-
 5)/B[2]→R[4]
46: wrt 16.1,
 R[2]," kilomete
 rs"
47: wrt 16.2,
 R[3]," statute
 miles"
48: wrt 16.3,
 R[4]," nautical
  miles"
49: fxd 2
50: spc 1
51: ent "# of
 nanosec/cm",
 N[2]
52: prt "# of
 nanosec/cm =",
 N[2]
```

```
53: spc 1
54: ent "T[0]
 in nanosec",
 T[5]
55: prt "T[0]
 =",T[5]," nanos
 ec"
56: spc 1
57: ent "# of
 cm for stack
 range in X.XX
 cm",R[5]
58: prt "# of
 cm for stack
 range =",R[5],
 " cm"
59: spc 1
60: R[5]*N[2]→R[
 6]
61: R[6]-T[5]→R[
 7]
62: R[7]*tn↑(-
 9)→R[8]
63: R[8]*C→R[9]
64: R[9]/100→R[1
 0]
65: 4→A[4]
66: 2*tn↑(-4)→P
67: A[4]+100*P*
 R[10]→D[3]
68: spc 1
69: ent "Laser
 output energy
 in joules/cm",Q
70: prt "Laser
 output energy
 =",Q," joules/
 pulse"
71: 1.27*Q*exp(-
 100*B[2]*R[10])
 /(D[3]*D[3])→H[
 1]
72: spc 1
73: ent "Plume
 opacity value
 in %",O[1]
74: prt "Plume
 opacity value
 =",O[1]," %"
75: spc 1
76: fxd 0
77: spc 1
78: prt "    *   *
   *   *    "
79: spc 1
```

```
80: prt "Lidar
 range to stack
 =",R[10]," mete
 rs"
81: fxd 2
82: O[1]/100→O[2
 ]
83: 1-O[2]→T[6]
84: H[1]*T[6]→H[
 2]
85: Q→A[5]
86: A[5]*exp(-
 100*B[2]*R[10])
 →A[6]
87: A[6]*T[6]→A[
 7]
88: 500*100→R[11
 ]
89: "cont":
90: R[11]+500*
 100→R[11]
91: A[4]+P*R[11]
 →D[4]
92: 1.27*A[7]*
 exp(-B[2]*R[11]
 )/(D[4]*D[4])→H
 [3]
93: 5*tn↑(-7)→Z
94: if H[3]>Z;
 gto "cont"
95: (R[10]+R[11]
 /100)/1000→R[12
 ]
96: .6214*R[12]→
 R[13]
97: .5396*R[12]→
 R[14]
98: spc 1
99: prt "   *  *
  *  *   "
100: spc 1
101: fxd 0
102: prt "Laser
 Beam Diameter
 at the Stack
 =",D[3]," cm"
103: spc 1
104: prt "Laser
 Beam Diameter
 at Eyesafe Dist
 ance =",D[4],"
 cm"
```

```
105: spc 2
106: prt "   *
 *  *  *    "
107: spc 1
108: prt "Lidar
 Eyesafe Distanc
 e:"
109: wrt 16.1,
 R[12]," kilomet
 ers"
110: wrt 16.2,
 R[13]," statute
  miles"
111: wrt 16.3,
 R[14]," nautica
 l miles"
112: spc 1
113: prt "   *
 *  *  *    "
114: spc 7
115: fxd 2
116: end
*31735
```

B(f) FAA Report Program (HP Language)

```
0: dsp "Report
 for  FAA Tower"
 ;wait 2500
1: dsp "Plot
 Lidar Position
 on Fl. Chart";
 stp
2: dim X$[9],
 Y$[25]
3: ent "Enter
 flight chart
 scale",X$
4: ent "Enter
 reference VOR",
 Y$
5: ent "Enter
 lidar dist.
 from VOR(mm)",L
6: ent "Enter
 lidar radial
 from VOR(deg)",
 R
7: ent "Magnetic
  bearing of
 laser (deg)",S
8: ent "Pedestal
  angle position
  (deg.)",T
9: ent "Ground
 elevation of
 lidar(ft)",G
10: ent "Enter
 eyesafe distanc
 e (Nmi)",H
11: H*6.076→H
12: sin(T)*H→P
13: P+G/1000+1→N
14: int(N)→N
15: dim A[N],
 B[N],C[N],D[N],
 E[N],F[N],J[N]
16: if X$="1:250
 ,000";L/7.4→L
17: if X$="1:500
 ,000";L/3.7→L
18: for I=1 to N
19: I*1000→A[I]
20: A[I]-G→B[I]
21: if B[I]<0;
 gto "one"
```

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```
22: B[I]/tan(T)→
 C[I]
23: C[I]/6076→C[
 I]
24: 180-abs(S-
 R)→K
25: √(L↑2+C[I]↑2
 -2*L*C[I]*cos(K
 ))→D[I]
26: (L↑2+D[I]↑2-
 C[I]↑2)/(2*L*
 D[I])→E[I]
27: deg;acs(E[I]
 )→E[I]
28: if abs(S-
 R)>180;gto "alp
 ha"
29: if S>R;R+
 E[I]→F[I];gto
 "one"
30: if S<R;R-
 E[I]→F[I];gto
 "one"
31: "alpha":if
 S>R;R-E[I]→F[I]
32: if S<R;R+
 E[I]→F[I]
33: if F[I]>360;
 F[I]-360→F[I]
34: if F[I]<0;
 abs(360+F[I])→F
 [I]
35: "one":next I
36: prt "Report
 for FAA  Tower"
 ;spc 2
37: prt "*    *
     *    *";spc
 2
38: prt "Referen
 ced to",Y$,"VOR
 , lidar truck"
39: fxd 1;prt
 "is located",L,
 "Nmi"
40: fxd 0;prt
 "on radial",R;
 spc 2
41: prt "*    *
     *    *";spc
 2
```

```
42: prt "The
 laser beam  is
 directed on  a
 magnetic
 bearing of",S;
 spc 2
43: prt "*    *
    *    *";spc
 2
44: prt "The
 laser beam
 passes through:
 ";spc 2
45: for I=1 to N
46: if B[I]<0;
 gto "two"
47: fxd 0;prt
 "Altitude
   (MSL)(ft)",
 A[I]
48: fxd 1;prt
 "at",D[I],"Nmi
 from the",Y$,
 "VOR on"
49: fxd 0;prt
 "Radial",F[I];
 spc 2
50: "two":next I
51: prt "*    *
    *    *";spc
 4
52: end
*1354
```

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